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Non-Fungicides-Based Promising Technologies for Managing Post-Production *Penicillium* Induced Spoilage in Horticultural Commodities: A Comprehensive Review

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ABSTRACT
Post-harvest commodities wastage due to decay caused by the pathogenic fungi generates a huge amount of economic losses worldwide. Different species of *Penicillium* spoil various foodstuffs and produce mycotoxins, alkaloids and other harmful cellular metabolites in the food. Presently, synthetic fungicides, mainly used for fungal diseases control, are associated with harmful impacts on the environment and consumer health. Hence, non-fungicide based eco-friendly and commercially viable alternative is proposed for ensuring food safety. In recent years, the safer options that have been explored include microbe mediated biological control, botanical pesticides, use of generally regarded as safe (GRAS) compounds, and innovative physical approaches including cold plasma, and pulsed light techniques. These emerging technologies could be utilized in the multiple hurdle concept of disease management for suppressing pathogens growth at different stages of spoilage development. This review, first of its kind, summarizes the exclusive information on *Penicillium* spp. induced spoilage, associated toxicological concerns and the potential of non-fungicide-based promising approaches for managing fungal wastage in the harvested horticultural commodities.

KEYWORDS
Penicillium decay; mycotoxins; biocontrol; antimicrobial botanicals; GRAS compounds; cold plasma

Introduction

The pathogenic decay of fruits and vegetables during the post-harvest storage and distribution stages causes a significant amount of losses and also limits their shelf-life.[1] According to an estimate of various intergovernmental agencies, more than one-third part of fruit and vegetables produced is wasted globally.[2] Even in developing countries, fungal decay is accountable for about 20–25% wastage of the total produce during post-production handling, storage, and shipment.[3] The huge amount of food wastage is due to fruit rotting, induced by a fungal infection, initiated either in a farm or after harvest that further develops into decay during the food supply chain. Harvested fruits bearing enough moisture and nutrients, acidic pH, and reduced intrinsic resistance become prone to fungal spoilage.[4] Numerous fungal species within the genera of *Penicillium, Botrytis,*

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Rhizopus, Monilinia, Aspergillus, Alternaria, Geotrichum, Fusarium, and *Gloeosporium* are responsible for some of the important storage rots of produce.[5]

Among the many pathogens, different species of *Penicillium* are accountable for some of the economically important storage decays of fruits. *Penicillium* are ubiquitous fungal genera that effectively colonizes wide natural habitats including soil, vegetation, several foodstuffs, air, and indoor environments.[6] The *Penicillium* genus includes about more than 150 species of anamorphic fungi in the Ascomycota division; however, only a small number of them are economically significant phytopathogens.[7] Worldwide, this fungal genus have a great impact in the agriculture and fruit industry due to large amount of qualitative and quantitative losses imposed to fruit growers by them. For example, post-harvest green mold (*Penicillium digitatum*) and blue mold rot (*Penicillium italicum*) of citrus fruits and blue mold (*Penicillium expansum*) spoilage of pome fruits are well notorious penicillium driven diseases resulting into huge monetary losses. Green decay of citrus fruits may account for about 90% of overall post-harvest losses.[8,9] Identically, almost 50% losses of total production have been reported in apple fruits due to blue mold spoilage incited by the cold-loving fungi *P. expansum*[10] In addition to the economic wastage, they have been recognized as potent producer of many toxic secondary metabolites such as various mycotoxins (including patulin, citrinin, and chaetoglobosins, etc.), antibiotics, alkaloids, and allergens, which are potentially carcinogenic, mutagenic and has a certain other negative impacts on human health.[11]

Traditionally, storage fungal decays are being managed through the pre- and after harvest use of chemical fungicides such as sodium thiabendazole, ortho-phenylphenate, and imazalil.[12] These fungicides effectively curb pre-existing, established or any new pathogen infections taking place in the storehouse. However, in recent years, the exploit of many synthetic chemicals for making food safe from such pathogens has been restricted mainly due to: (i) appearance of pathogen resistance towards many important fungicides, (ii) emergence of new pathogen races, (iii) paucity of an effectual, alternative, and suitable fungicide, (iv) concern over presence of toxic residues on commodities, (v) toxicological concerns of harmful fungicides to human, animal, and ecosystem health.[13] Due to all these concerns, more scientific attention has been given for the development of non-fungicide based safer and eco-friendly alternative strategies for managing *Penicillium* as well as other fungal decay/rots.

Among the safer options, antagonistic microbes (bacteria, yeast, and yeast-like fungi), obtained from diverse sources of plant surface, rhizosphere, agricultural soil, sea, and extreme niche have been explored for storage disease control in last few decades. The biological control via such microbial antagonists is a promising and ecological sound option for controlling fungal rotting.[14] The bio-control approach is more advantageous owing to non-residual toxicity, eco-friendly, safe for application, cheaper to produce, and have wider public acceptance.[15] Another biological alternative is use of botanical extracts, essential oils, and antimicrobial compounds having biodegradable and non-toxic nature, as botanical pesticides for managing fungal decays.[16] Apart from these, the perspectives of novel physical treatments including cold plasma and pulse light processing technology[17] and importance of produce sanitation in reducing rot pathogens inocula,[18] as both a separate practice and in combination have been also demonstrated. In recent past, machine vision approaches including hyperspectral imaging have been used in the safety evaluation of horticultural produce bearing nonvisible microbial incited spoilage.[19–21]

The ultimate aim of such practices is to prevent the growth of pathogen so that spoilage induced by them is reduced by a large extent. These several approaches acting together additively or complementary can control the *Penicillium* infections to a required level (97–99%). Furthermore, multiple point hurdle approach, being used for managing food-borne pathogens in the food industry, can be similarly used for the controlling spoilage and ensuring produce safety during the food supply chain.[22] As a result, such manifold technologies, capable of suppressing pathogen at different stages in the disease development, could be explored in the multiple interventions/hurdle concept of disease management. Here, the present review with latest studies summarizes the exhaustive literature information on *Penicillium*-induced fungal decays, myco-toxicological concerns and non-chemical based safer and potent emerging approaches especially focused on curbing its infection in the harvested commodities.

Significance of *Penicillium* mold in the post-harvest and storage environment

Penicillium is one of the most frequently occurring fungal genera mainly during post-harvest handling, storage, and shipment stages of fruits and vegetables. The genus *Penicillium* is r-strategic fungi with the ability of rapid multiplication and thriving in sparsely populated and resourceful environments.[23] Depending on the pathogen–host interaction and specificity, fungal growth may occur as an epiphytic that eventually affect the export perspective and market potential of the fruit.[24] The pathogen produces many hydrolytic enzymes that enable them to pierce into host tissue. The rapidly occurring cross-contamination of healthy fruits from infected and spread of inoculum into the surrounding environment signify the economic importance of *Penicillium* spoilage during the food supply network. *Penicillium* is an aggressive pathogen and capable to spread, invade, and colonize the various environments under the right set of growth conditions. The pathogen can directly penetrate fruits through the wound or injuries present on the fruit surface. The colonization of fruit wounds may often keep other parts of fruit devoid of infection even if it is delimited by a lot of contaminated fruits.[25] In humid storage, fruiting bodies of *Penicillium* spp. appears as blue-green coloration on the infected fruits, which subsequently develop into decay. The infected fruits emit earthy and musty odor, mainly due to the compound named to as "geosmin, produced by the blue mold fungus, *P. expansum* as well as other few species of *Penicillium*.[26]

The most common encountered *Penicillium* rots in fruits predominantly includes green mold and blue mold spoilage. They are the most ubiquitous and catastrophic of all post-harvest fungal spoilage of many fruit and vegetables. Green and blue molds are the principal fungi nearly accounting for up to 90% of fruits spoilage during the phases of storage, transit, and marketing. The decay inflicting fungi are necrotrophic pathogens and produces several hydrolytic enzymes, particularly pectinase, polygalacturonases, and cellulases, all of which macerates fruit tissue during the process of disease expansion.[27] Following the invasion, fungi utilize host nutrients for spore germination, growth, and metabolism. The pathogens extensively produce spore that ensures its all over presence in the field, packing house, equipment, storage room, transit containers, and in the marketplace too. Their spores are airborne, hence, can spread from infected fruit to healthy and surrounding environment in the packing house. The stem end or even sound parts of the rind also mediate the pathogen infection and its further spread. In general, long time cold-stored fruits deteriorate and spoil rapidly, as a consequence of loss in intrinsic decay resistance of fruits.

As reported in Table 1, diverse species of *Penicillium* causes decay in several harvested fruits and vegetables. Among them, green mold rot caused by *P. digitatum* is most destructive after harvest disease mostly reported in citrus family fruits worldwide. However, other fruits such as papaya, apple, pear, tomato, persimmon, beet, Arabian coffee, melon, abisin, iris, golden berry, and tamarind have also been reported as its hosts. Moreover, the fungus has been occasionally isolated from other foods such as pistachio, hazelnuts, kola nuts, peanuts, soybeans, rice, and sorghum.[53] This fungus can grow at 5°C and as high as at 37°C. Growth of fungus is slow at low temperature while it multiples rapidly at slightly higher temperatures (25–30°C), growth is fast. Therefore, decontamination of orchard and packinghouse is often required to restrict its sporulation and dissemination on adjacent fruits during the phase of storage and shipment. Likewise, *P. expansum* is a broad spectrum pathogen largely known for inciting blue mold spoilage in several harvested fruits of the deciduous tree including apples and pome.[54] It is the only *Penicillium* sp., capable of showing pathogenicity in pome fruits, stone fruits, citrus, and grapes. The fungus may also induce spoilage in avocados, mangoes, strawberries, and tomatoes, nectarines, plums, kiwifruits, and even citrus fruits. Though unusual, it even infects certain vegetables like onions, carrot, and cabbages.[33] The pathogen spores from

Table 1. Different species of *Penicillium* reported as etiological agents of decay occurring in several fruits and vegetables during post-production handling and storage.

Penicillium species	Post-harvest disease	Host fruit(s)/vegetable(s)	References
Penicillium digitatum	Green mold	Citrus family fruits including citrus, lemon, mandarin and orange	[28, 29]
Penicillium italicum	Blue mold	Citrus family fruits including citrus, orange, mandarin, and lemon	[30 31]
Penicillium expansum	Blue mold	Apples, pears plums, peaches, apricots, cherries, kiwifruits, blackberries, melons, strawberries, citrus fruits, jujube and certain vegetables such as onions, garlic and cabbages	[32–37]
Penicillium crustosum,	Blue mold	Pears and apples	[38, 39]
Penicillium solitum	Blue mold	Pears and apples	[38, 39]
Penicillium glabrum	Post-harvest decay	Strawberries and pomegranate	[40]
Penicillium chrysogenum	Post-harvest rot	Grapes and tomatoes	[41]
Penicillium claviforme	Post-harvest storage rot	Sugarbeet	[42]
Penicillium herquei, Penjcillium implicatum, Penicillium glabrum, Penicillium minioluteum, Penicillium purpurogenum, and *Penicillium sclerotiorum*	Post-harvest decay	Pomegranate	[43–46]
Penicillium adametzioides	Fruit decay	Pomegranate	[47]
Penicillium juntculosum	Fruitlet core rot	Pineapple	[48]
P. olsonii P. solitum and *P. polonicum*	Post-harvest decay	Tomato	[49]
P. bialowiezense, P. citrinum, P. echinulatum, P. expansum, P. solitum	Blue Mold	Grape	[50]
Penicillium commune	Fruit decay	Litchi	[51]
Penicillium bialowiezense	Reported as pathogenic	Chestnut	[11]
Penicillium sclerotigenum and *P. polonicum*	Blue mold	Yam	[52]

the soil, diseased fruits, surrounding air, washing water, and drenching solutions also cause infection in the harvested fruits. The fungus has significant socio-economic impacts and several concerns for international trade. *P. italicum* is another important wound-obligate pathogen responsible for economically important blue bold decay in citrus fruits.[31] Both green and blue mold pathogens have a comparatively small disease cycle of 3 to 5 days at 25°C and, on a particular fruit, can produce 1 to 2 billion conidial spores. The pathogen occurrence is more common on fruit held at low-temperature storage. Furthermore, it can spread in packed cartons more rapidly than green mold and thus become more harmful to fruits held in the box. On the contrary, green mold pathogen does not spread by nesting; thus, if a single fruit is affected it remains as such without contaminating adjacent fruit.

Penicillium mycotoxins and related issues

Penicillium mycotoxins and factors affecting their biosynthesis in the infected foodstuffs

In addition to commodities spoilage, certain species of *Penicillium* are involved in the production of different mycotoxins, antibiotic compounds, alkaloids, and allergens that are potentially lethal to human and animal health.[11] Some of the toxic secondary metabolites secreted by them are citrinin, chaetoglobosin, cyclopiazonic acid, penicillic acid, communesin B, expansolides, and roquefortine C. The mycotoxins, being major harmful compounds in foodstuffs, produced by different *Penicillium* species include (1) patulin, penicillic acid, ochratoxin A, cyclopiazonic acid, and roquefortine C produced by *P. chrysogenum*; (2) citrinin, penicillic acid, ochratoxin A, cyclopiazonic acid, viomellein, xanthomegnin, and viridicatin secreted by *P. viridicatum* and; (3) paspalinines, janthitrems, and paxillines mycotoxins of *P. tularense*.[55,56]

P. expansum is a major spoilage pathogen accountable for patulin production in stored fruits, principally in pome fruits and their processed products.[57] Patulin is the most prevalent and dangerous mycotoxin of pathogenic *Penicillium*. It is a water-soluble, comparatively non-complex and lactone containing toxin. White et al.[58] demonstrated that the patulin biosynthesis process is facilitated at the gene transcription level. They revealed inclusion of several enzymatic steps in the metabolic pathway of patulin synthesis from the polyketide, and 6-methylsalicylic acid. Further, they observed enhanced expression status of all the five metabolic pathways cloned genes including isoepoxydon dehydrogenase (IDH) gene, and fragments of the 6-methyl salicylic acid synthase gene, putative ATP-binding cassette transporter gene, and two putative cytochrome P450 monooxygenase genes in pathogen under patulin favorable situations, signifying their probable involvement in patulin biosynthesis. Recent advances in genomic studies of *P. expansum* have aided in the identification of several genes concerned with the patulin biosynthesis. These are patulin cluster genes including, patE, patG, patH, patI, patK, and patL,[54–59-61] the LaeA, gene credited for the global regulator of secondary metabolism,[62] PeSte12, the transcription factor,[63] LysM effectors,[64] and the SdnB, subunit of respiratory complex II.[65] Although *P. expansum* inflict blue mold decay in numerous fruits, however, the main source of patulin contamination is found in the decayed apples. The quantity of patulin produced and accumulated in fruit varies with the *Penicillium* strain concerned.

The biological function of fungal secondary metabolites including numerous mycotoxins is still vague. However, the most prevalent notion is that mycotoxin production allows fungi a better protection against other organisms inhabiting the same ecological niche. Certain mycotoxins may have a role fungal aggressiveness and pathogenicity during the process of host exploration.[66] For example, the extracellular patulin production by *P. expansum* aids in the effective host tissue colonization. Many authors have investigated the probable role of secondary fungal metabolites, mainly of patulin, in pathogen virulence. More recently, an investigation by Barad et al.[67] showed the possible cytotoxic effect of patulin accumulation on the host cell, which indicated patulin dependent pathogenicity of *P. expansum*. In another study, patulin production by pathogen and its direct association with blue mold incidence on apples have been reported.[68]

The mycotoxin production in an infected produce is affected by numerous environmental factors that significantly affect the growth rate, metabolism, and development of fungi.[69] The storage temperature, ambient pH, humidity, and water activity are among the main factors influencing pathogen growth and toxin secretion.[70] The production and accumulation of extracellular patulin are also reliant on a range of multifarious interactive factors including the geographical location of fruits growing, the variety and fruit type, harvesting, maturity status, and other physiological attributes of fruits, quantum of pathogen inoculums on fruit, and fungal species concerned. The patulin production in apples, stored under controlled atmosphere conditions of 3% CO_2 and 2% O_2 was reduced consistently with time.[71] The pH levels modulate the toxin accrual during the process of fruit colonization. Many authors have positively correlated the continuous buildup of patulin concentration with the acidic conditions.[59–72] The pH range and patulin accumulation are conversely linked and patulin is found to be unstable at higher pH level.[73] However, the elevated expression level of pePatN, the gene coding for IDH at neutral pH compared to acidic suggest the alkaline regulated transcription factor, PacC, might have an influence on pePatN.[74] In fact, *P. expansum*, owing to reduced available carbon sources in media, releases a large amount of ammonia, which may regulate the activation of PacC and thus patulin accretion in apples. The patulin production has been recorded at all temperature range (0–30°C) essential for optimum growth, development, and metabolic activities of *P. expansum*.[75]

Myco-toxicological concerns and prevailing government's regulations

The patulin accumulation is found in both organic and conventional produced fruit and its derived products. However, a significantly higher level of patulin concentrations was detected in organically produced foodstuff than do conventional produce.[76] More recently, a survey performed by Sarubbi et al.[77] (2016) on baby foods revealed considerably higher amounts of patulin occurrence in organically grown products compared to traditional ones. This has raised the call for stricter pre-processing control of fruits cultivated under organic agriculture. Occasionally, even if apple products are free from patulin contamination, they may contain other toxic secondary metabolites, herein, detection of related toxin such as chaetoglobosin A, rather than patulin could be a better indication for the existence of *P. expansum*.[56] The patulin incidence in fruit products, particularly in apple products is being recorded globally. Apple juice and cider continue to be the main source of human patulin consumption.[78] The frequency of patulin and related mycotoxins has been compared vis a vis in organic and conventional grown fruits, homemade and industrial prepared fruit products, and in a hazy and in clear fruit juice.

The consumption of spoiled fruits and their products, contaminated with mycotoxins poses a severe risk to consumer's health. It may have toxicological effects on human including carcinogenic, mutagenic, nephrotoxic, neurotoxic, teratogenic, hepatoxic, and genotoxic. Although there is no apparent proof about human carcinogenicity, however, it has shown some immunotoxic and neurotoxic effects in animals.[79] Therefore, the European Union Commission has regulated (Regulation No. 1881/2006) and established the maximum permissible levels of patulin in foodstuffs. Further, joint expert committee of Food and Agriculture Organization (FAO) and World Health Organization (WHO) has kept an interim daily upper limit of patulin intake of 0.4 mg per kg body weight.[80] On a similar line, the US Food and Drug Administration has restricted patulin amount to 50 mg L^{-1} in single-strength and restored apple juices.[81]

Emerging technologies for the management of post-harvest *Peniciilium* incited diseases/decay

Biological control of Penicillium spoilage using antagonistic microorganisms

Antagonism is the process whereby activities of one organism impede the growth, metabolism, and development of pathogen present in their vicinity. Such organisms are termed as "Biological Control Agents (BCAs)" and are fitting candidates for managing economic pests and diseases of crops.[82] Among the non-chemical-based approaches, antagonistic microbes mediated disease suppression is an emerging and more eco-friendly option.[83] Numerous microbes, possessing inhibitory attributes against pathogens, are utilized in controlling fungal decay during commodities storage. In biological control, the suppression of pathogen activities is achieved through actions of antifungal metabolites produced by the BCAs. The BCAs explored for fungal decay control belong to taxonomic groups of yeast, bacteria, and filamentous fungi.

In recent past, several different kinds of microbial antagonists, isolated from fruits and vegetable surface, phyllosphere, root, rhizosphere, orchard soil, Antarctic soil, and ocean, have been used in the biological control of *Penicillium* and related fungal pathogens occurring on harvested fruits.[14] Some desirable features of biocontrol strains for their use as effective post-harvest biocontrol agent must include; (1) genetic stability and effective at low concentrations, (2) need for simple growth factors, (3) longer storage life and ease of application, (4) tolerance to generally used post-harvest fungicides, (5) non-pathogenic to human, (6) ability to survive under adverse conditions and better adaptability under given set of environment, and (7) user-friendly with other chemical and physical methods.[14–84] Furthermore, higher cell viability of biocontrol microbes is also required for their use on the commercial scale.

The antagonistic yeasts have been more often employed for managing *Penicillium* infection of stored produce. Their ability of fast proliferation, rapid colonization of fruit surface under adverse environment, quick utilization of host nutrients and thus, making it unavailable for pathogens growth and increased endurance due to extracellular matrix production make them suitable as successful post-production BCA.[85] Additionally, they are more ecological competitive due to the secretion of extracellular proteinous toxins, as observed in some yeast strains such as *Hansenula, Saccharomyces, Pichia*, and *Kluyveromyces*.[86,87]

Zhang et al.[88] showed the biocontrol efficacy of antagonistic yeast *Wickerhamomyces anomalus* against blue mold decay of pears and demonstrated the significant impact of yeast on the reduction of spore germination and germ tube length of the pathogen along with minimizing disease incidence on pear fruits. Authors observed a disease incidence of only 5.56% in pears treated with 1×10^8 cells mL^{-1}, as compared with 100% disease occurrence in the control. Moreover, expression levels of defense-related enzymes were drastically stimulated by *W. anomalus* in the host. In another recent study, results of Wang et al.[89] experiment showed bioprotection ability of novel antagonist yeast *Yarrowia lipolytica* against storage decay of grapes incited by *Penicillium rubens*. They observed a significant reduction of fungal decay and disease incidence when biocontrol strain was applied at the 1×10^9 cells mL^{-1}. Further, considerable inhibition of pathogens spore germination, germ tube elongation, and activation of pathogen defense-related gene expression, following the inoculation of the biocontrol yeast strain, was noticed in the fruits. In a similar manner, control of *Penicillium* rot in many other fruits have been achieved using several antagonistic strains of yeast such as *Aureobasidium, Candida, Cryptococcus, Pichia, Wickerhamomyces*, and *Debayromyces*, etc.[90–94]

Similar to yeasts, antagonistic bacteria possessing potent antifungal and antibacterial potential are also explored as natural bioagents for suppressing *Penicillium* proliferation.[95,96] Regarding the bacterial-mediated post-harvest biocontrol, the work of Wallace et al.[10] reported the disease suppression ability of *Pseudomonas fluorescens*, a soil rhizobacteria isolates, against *P. expansum* causing blue mold decay on the apple fruits. Application of this bacterium reduced decay incidence on fruits held during cold storage after 15 weeks of periods. With the aid of in vitro and scanning electron microscopy (SEM) studies, pathogen inhibition ability of strains was attributed to the mechanisms of nutrients and space competition and production of growth inhibitory metabolites, that probably targeting conidial germination and mycelia inhibition. In another work, bacterial bioagent such as *Bacillus subtilis* and *Agrobacterium radiobacter* exhibited significant antifungal activity against the green mold pathogen of lemon fruits, possibly due to the production of cell wall lytic enzymes (chitinase and glucanase). These strains caused negative impacts on the mycelial growth and spore germination of the pathogen and considerably reduced disease severity of *P.digitatum* on lemon fruits under in vivo conditions.[97] Similar to these works, the inhibition of *Penicillium* growth in various fruits has been obtained using different strains of bacterial antagonists such as *Bacillus, Agrobacterium, Pseudomonas, Pantoea*, and *Streptomyces*.[98–101]Among them, some of the bacterial biocontrol strains have been formulated and developed into marketed products for curbing fungal decay. In addition to yeasts and bacterial bioagent, certain fungi also protect the harvested fruits from the infections of numerous *Penicillium* spp. Within fungal genera, few species of *Trichoderma, Aureobasidium*, and *Verticillium* have received interest as post-production biocontrol agents.[99–102,103] The fungal biocontrol activities are mainly due to the nutrient competition, mycoparasitism, antifungal compounds production, and stimulation of host defenses.

Mechanisms of microbial antagonists involved in the control of Penicillium decay

The mechanisms involved in the biological suppression of decay pathogen include nutrients and space competition, production of antibiotics and cell wall lytic enzymes, and stimulation of host defense.[104] Furthermore, some recent studies have elucidated the important role of quorum sensing, biofilm formation, mitigation of host oxidative stress and production of biocidal volatiles in the pathogen biocontrol.[14] These mechanisms are interlinked and operate in a tritrophic interaction system involving microbial antagonist, the fungal pathogen, and host fruit (Fig. 1). Often, simultaneously more than one mode of antimicrobial action contributes to the effective biological disease suppression.

The successful competition between antagonist and pathogen for the available nutrients such as sugar, vitamins, amino acids, and minerals, and limiting space results in pathogen biocontrol.[105] This antifungal action is reported in many microbial antagonists.[3–106] As discussed in the previous section, a microbial antagonist rapidly diminishes the available nutrients oozed from fruit wound, and hence, it became unavailable for pathogens reproduction and virulence. In fruit wounds, competition usually occurs for the amino acids, vitamins, and oxygen, when present in the low level. Bencheqroun et al.[107] showed the importance of the competition process in the inhibition of apple blue mold pathogen, *P. expansum* by the yeast antagonist *A. pullulans*. They found that the biocontrol efficacy of yeast strain against fungi was improved increased when a concentration of amino acids was limiting in the fruit wounds. Rapid multiplication and production of extracellular sugar matrix are the most vital traits of yeast antagonists competing with the pathogen for colonizing limited space. Siderophore, a low molecular weight iron chelator compound

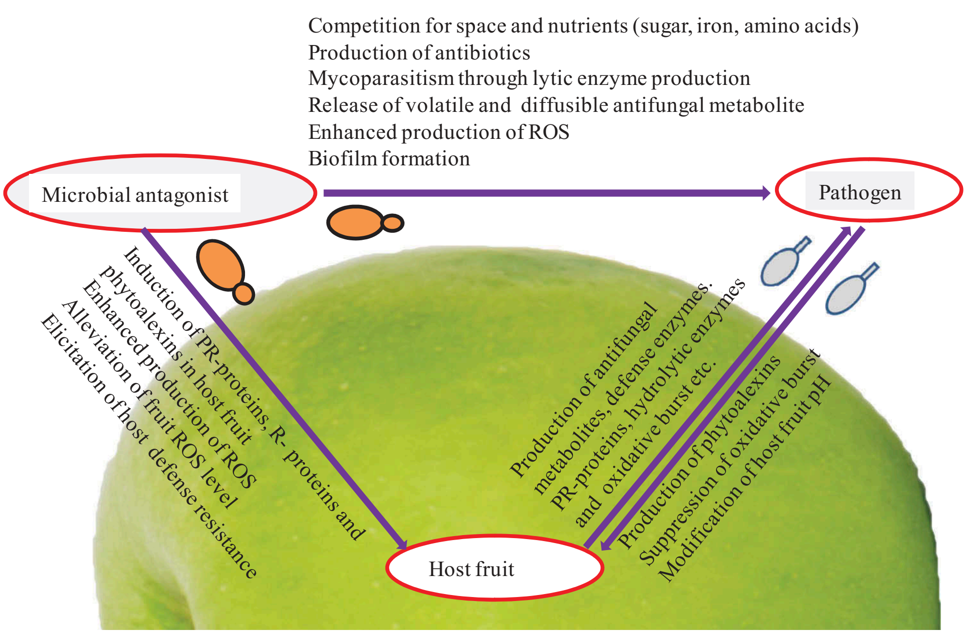

Figure 1. Schematic diagram illustrating the probable mechanisms of antagonistic microbes mediated post-harvest biological control actions involved in tritrophic interaction system, comprising the microbial antagonists, decay inflicting pathogen and host fruit. Adapted after modification from Dukare et al.[3]

produced by biocontrol strain is also involved in retarding the pathogens growth, reproduction, and pathogenicity. Siderophore compounds make iron nonaccessible for pathogen by forming a firm complex with ferric ions of medium and bringing it into the cytoplasm.[108] The work of Saravanakumar et al.[109] related to siderophore-mediated biocontrol revealed that siderophore (pulcherrimin) producing yeast antagonists *Metschnikowia pulcherrima* and *M. fructicola* impeded conidial germination of apple rotting fungi (*P. expansum, B. cinerea*, and *Alternaria alternate*) under the limited iron concentration in the medium. Following iron depletion in the growth medium, complex and multiple physiological reactions were triggered in the pathogen hyphae resulting in the disintegration and breakdown of fungi mycelia structures.[109] Similarly, the biocontrol potential of the bacterium, *Rahnella aquatilis*, against apple decay pathogens (*P. expansum* and *Botrytis cinerea*) is linked with its ability to produce siderophore.[110]

The production of fungal cell wall lytic enzymes is another important way by which antagonist suppresses pathogen proliferation. Such enzymes cause mycoparasitism via attaching and degrading fungal hyphae. In the process, pathogens propagules are killed and cellular structures and cellular integrity get destroyed. The fungal cell wall, composed of chitin and glucan in combination with wall protein, is disintegrated by an individual or collective actions of lytic enzymes such as chitinases, glucanases, chitosanases, cellulase, and protease produced by antagonists[105] Moreover, these enzymes adversely affect pathogens conidial germination, germ tube elongation, and reproductive structure.[111] Accordingly, several reported biocontrol strains of *Penicillium* spp. produce extracellular hydrolytic enzymes. For example, the biocontrol action of antagonist yeast *C. oleophila*, against *P. expansum*, causing blue mold decay in the apple was mediated through cell wall degrading β-1, 3-glucanase enzyme.[91] Authors observed that the action of purified glucanase reduced pathogens conidial germination and mycelia growth. The antimicrobial actions of many species of *Bacillus* and *Pseudomonas* are credited to extracellular chitinase released by them.[112] Detrimental effects of enzymatic actions on pathogen hyphae include cellular deformities, protoplasmic damage, mycelial distortion and lyses, leakage of cellular contents, and changes in membrane permeability.[104] Therefore, the loss of fungal cytoplasm resulting from cell wall disintegration is one of the key modes accountable for biocontrol actions of antagonists.

Some bioagents prevent pathogens development by releasing growth-retarding antibiotic compounds. The antibiotics producing species of bacterial genera, predominantly *Bacillus* and *Pseudomonas* are well recognized for their antifungal potential. For example, the antibiotic "pyrrolnitrin" producing bacterium, *Pseudomonas cepacia* controlled *P. digitatum* on lemon and *P. expansum* and *Botrytis cinerea* on apples.[104] Similarly, an antibiotic, syringomycin producing *Pseudomonas syringae* managed citrus green mold disease, inflicted by *P. digitatum*.[106] The antibiotic compounds restrain pathogen development through the cell membrane damages, prevention of cell wall biosynthesis and disruption in the protein assimilation process.[113]

The external application of BCAs often induces systemic resistance (ISR) to invading pathogens in the host tissue.[114] The ISR process involves the accretion of structural barriers and stimulation of various biochemical and molecular responses including mitogen-activated protein kinase signaling, production of reactive oxygen species (ROS), phytoalexins and PR-proteins, synthesis of terpenoid and phytoalexin, increased synthesis of phenolics, cellular lignifications, glycoproteins, and callose.[115] The induction of host defenses against *Penicillium* spp. following BCAs application had been shown. For example, peach fruits, when treated with antagonistic yeast, *C. laurentii* in combination with methyl jasmonic acid triggered the elevated activities of several defense proteins such as chitinase, glucanase, phenylalanine ammonia-lyase, and peroxidase, which further reduced disease lesion diameter of *P. expansum* and *Monilia fructicola*.[116] Differential changes in gene and protein expression levels in response to BCAs application have been also demonstrated in both antagonists and host tissue. These changes contributed to augmented host defense to attacking fungal pathogens.[117]

Apart from these, other reported mechanisms of post-harvest biological disease control, though minor in action, are the production of antifungal volatile metabolites.[118] This mode of action is implicated in the growth inhibition of *Penicillium* spp. on several fruits and has shown in certain bacterial, fungal, and yeast BCAs.[119–120] The undesirable effects of fungicidal volatiles on the pathogen, as revealed by SEM studies, included several cellular deformities like negative changes in cell vacuolation and membrane permeability, swelling and breakdown of hyphae, reduced conidial germination, and formation of aspersoria.[121] Likewise, biocontrol strain mediated production reactive oxygen species (ROS), oxidative stress mitigation, and biofilm formation are some other modes documented in the control of *Penicillium* spp. and other fungal pathogens.[3] The list of microbial antagonists and their reported mechanisms of biocontrol action against post-harvest *Penicillium* induced diseases/decay on several fruits have been shown in Table 2.

Use of plant-derived botanicals for controlling fungal spoilage

Plant-derived botanical compounds of antifungal nature also have a potential for the controlling fungal decay of storage commodities in an eco-friendly manner. Presently, considerable attention is being given towards developing the botanical fungicides for controlling the diseases of harvested fruits. More than thousands of plant species and ten thousands of its secondary metabolites are a vast depository of different antimicrobial compounds.[140] The antifungal botanical compounds Essential oils (EOs), natural products, and crude plant extracts are biodegradable, non-toxic, and are regarded as GRAS to mammal's health; hence, they have a huge potential for their use in integrated disease management.[141]

Essential oils (EOs) are naturally occurring complex and volatile compounds having antimicrobial, medicinal, and anti-oxidative potential.[142] They are regarded as GRAS by the U.S. Food and Drug Administration.[143] In the last decade, plant EOs have been used in food and pharmaceutical industry as antifungal, anti-mycotic, and pest control agents.[144] Their use in fungal spoilage control is more preferred mainly due to (1) more volatile, biodegradable, and of ephemeral nature, (2) no concern over presence of residual toxicity on produce, (3) low possibility of developing resistance in pathogen, and (4) in addition, most of the EOs components have no definite cellular targets.[145]The wide variety of EOs obtained from various plants such as clove, cinnamon, oregano, lemongrass, thyme, basil, and nutmeg are most widely used as natural fungicide and food preservatives.[146] Many researchers have used various plant-derived EOs in the management of storage pathogens of fruits and vegetables.[147–149] In fungal growth control, thyme and cinnamon EOs significantly reduced the *Penicillium* spp. driven green and blue mold incidence on harvested citrus fruits and also controlled the occurrence of other

Table 2. Representative lists of microbial antagonists and reported mode of their actions implicated in the biological control of post-harvest *Penicillium* diseases/decay on different fruits.

Microbial antagonist(s)	Target pathogen(s)	Host	Reported mode of action	References
Yeasts/fungal antagonists				
Pichia membranaefaciens	*Penicillium expansum*	Peach	Release of lytic enzyme and activation of host defense	[122]
Pichia caribbica	*P. expansum*	Apples	Activation of host resistance via production of defense proteins	[123]
Cryptococcus laurentii	*P. expansum*	Pear	Release of lytic enzyme	[112]
Cryptococcus laurentii	*Penicillium italicum*	Jujube	Nutrient and space competition	[124]
Cryptococcus laurentii, *Candida sake*	*Penicillium digitatum*	Orange	Nutrient competition	[125]
Rhodotorula glutinis	*P. digitatum*	Citrus	Nutrient and space competition	[126]
Rhodotorula mucilaginosa	*P. digitatum*	Oranges	Activation of host resistance via production of defense proteins	[127]
Debaryomyces hansenii	*P. digitatum*	Citrus	Nutrient and space competition	[128]
Kloeckera apiculata	*P. italicum*	Citrus	Nutrient and space competition	[129]
Metschnikowia fructicola	*P. digitatum*	Grapefruit	Induction of pathogen defense related proteins in host	[130]
Rhodosporidium paludigenum	*P. digitatum*	Citrus	Induction of host resistance and pathogen defense system	[131]
Meyerozyma guilliermondii	*P. expansum*	Pears	Stimulation of antioxidant enzymes activities and defense protein in hosts	[132]
Aureobasidium pullulans	Blue mold	Grapes	Nutrient competition; Induction of host resistance	[133]
Trichoderma harzianum	*P. expansum*	Pears	Not reported	[134]
Muscodor albus	*P. italicum*	Lemon	Antifungal volatile compounds production	[135]
Verticillium lecanii	*P. digitatum*	Citrus	Induction of resistance	[103]
Bacterial antagonists				
Bacillus subtilis	*Penicillium digitatum*	Citrus	Antibiosis production	[95 98]
Bacillus amyloliquefaciens	*Penicillium crustosum*	Citrus	Antibiotic production	[119]
Bacillus subtilis *Agrobacterium radiobacter*	*P. digitatum*	lemon	Production of mycolytic enzymes	[97]
Pseudomonas spp.	*P. digitatum*	Orange	Nutrient and space competition	[99]
Serratia plymuthica	*Penicillium* spp.	Citrus	Antibiosis and nutrients competition	[136]
Pantoea agglomerans	*Penicillium* spp.	Citrus	Not detected	[137]
	P. digitatum	Citrus	Triggers H_2O_2 production and enzymatic activities	[100]
Pantoea agglomerans	*P. digitatum* *P. italicum*	Mandarin	Nutrient competition	[138]
Streptomyces globisporus	*P. italicum*	Citrus	Release of lytic enzyme	[101]
Enterobacter cloacae	*P. digitatum*	Citrus	Production of antifungal volatiles	[139]

fungal rots. In a similar way, treatment of apples with oregano, clove, and cinnamon EOs effectively restricted fungal spoilage of *Penicillium* spp. The result showed that penicillium infection was absent in 14% of the apples kept in control, on the contrary, 39–42% of the oregano-treated samples lacked fungal infections.[150] The antifungal profile of EOs can make them a feasible alternative to the synthetic fungicides used in controlling storage pathogens. The mechanism by which EOs' restrain the growth of pathogens is not clearly deciphered, though; suggested assumptions explicate their antifungal activity. These include (i) adverse modification of cellular enzymes and intracellular organelle functions due to OH groups presence and multiple hydrogen bonds formed by EOs, (ii) morphological alteration due to destruction of cellular firmness and integrity, (iii) destabilization of cellular membrane, and (iv) disruption in the membrane permeability and cytoplasmic granulation.[151–154]

The plant-derived secondary metabolites encompass a broad array of antimicrobial compounds including alkaloids, EOs, flavonoids, phenols, quinones, saponins, sterols, and tannins.[141] Among them, compounds that exhibit promising antimicrobial activities are acetaldehyde, allicin, benzaldehyde, glucosinolates, isothiocyanates, hexanal and hexanol, methyl salicylate, benzyl alcohol, ethyl formate, jasmonates, and lipoxygenases, etc.[155,156] Generally, phenolic substances, the main group of secondary metabolites, contain more than 8,000 phenolic structures and are found in many genera of a different plant family.[146] The proposed actions that are responsible for their fungicidal properties includes (i) disruption and dysfunctioning of cellular membrane, (ii) inhibition of cellular enzymatic activities, spore germination, germ tube extension and mycelia development, (iii) interference with ATP production and dissipation of electrical potential and pH gradient, and (iv) enhanced production of ROS that causing conformational changes in the membrane proteins.[157,158] The capability of different phenolic compounds in inhibiting rot causing fungi in multiple foodstuffs has been documented. For example, phenolic compounds of herbaceous plants origin effectively managed the growth and development of *P. digitatum, Monilinia laxa*, and *Botrytis cinerea*, all of which are responsible for post-production spoilages on oranges, nectarines, apricots, and table grapes, respectively. Additionally, these compounds lowered the incidence of green mold on oranges by about 92%, when observed after the 25th day of post-treatment storage.[159] Likewise, the report of Sanzani et al.[160] showed the effectiveness of several phenolic compounds (such as ferulic acid, esculetin, quercetin, scopoletin, resveratrol, scoparone, and umbelliferone) in controlling the blue mold infection of *P. expansum* on "Golden Delicious" and "Granny Smith" apples. However, quercetin and umbelliferone were found the most effectual, preventing *Penicillium* decay by about 86–92%. In addition tophenolics, certain other plant originated antimicrobial metabolites such as acetaldehyde, benzaldehyde, cinnamaldehyde, ethanol, benzyl alcohol, nonanone, and nerolidol, citral were also effective in protecting citrus fruit from the spoilage of pathogen *P. digitatum*.[155–161] Citral is an active compound found in the citrus fruit peel that hampers pathogen (*P. digitatum*) growth and spore germination,[161] and initiates host defense against this pathogen.[162] The role of different isothiocyanate in reducing the incidence of apple spoilage pathogens (*P. expansum* and *B. cinerea*) by up to 85% has been demonstrated.[163]

The extensive screening on novel plant extracts of potent fungicidal nature has been done and constantly being performed worldwide. The antifungal properties of both aqueous and organic solvent-based plant extracts against several pathogens of harvested citrus, apples, pear, and other fruits have been reported.[164–168] In general, method/solvent employed for plant extracts extraction influences its antifungal activity, probably due to the polarity of solvent used for extraction. For example, methanol, a polar solvent, can remove many plants antimicrobial compounds such as phenolic compounds, alkaloids, tannins, triterpene glycosides, and sesquiterpene lactones.[141] Their antimicrobial action is due to the presence of a large number of bioactive ingredients.[145] Some extract, for example, methanol extracts of *Withania somnifera* and *Acacia seyal* control the green mold infection via induction of host defenses.[165–169] The antimicrobial activities of crude plant extracts are documented; however, an in-depth assessment of their biological activity, phytotoxicity, dispersal in fruit tissues, and formulation development requires scientific attention for their use as botanical pesticides on the economic scale.[170]

In regards to their delivery,, they can be applied by incorporating into coatings of fruits or dipping fruits in the concentrated solution of botanicals containing EOs, plant extracts or secondary metabolites.[148–171] Their use by incorporating it into fruit coating is more popular, as, it allows closer and longer interaction with the pathogen on the fruit surface, hence, resulting in the successful control of decay pathogens.[171] In order to develop an effective antimicrobial plant compound into botanical fungicide, they must be: (a) effective at lower concentrations, even at short duration treatments, (b) should not have adverse effects on, aroma, flavor, and acidity of produce, and (c) the lowest appropriate dose for practical application.[140–170] The partial list of some plant-derived antifungal botanicals against different species of post-harvest decay-causing *Penicillium* have been given in Table 3.

Sanitation as effective means for microbial decontamination and managing *Penicillium* rotting of fruits

To a certain extent, indirect control of food spoilage is achieved through sanitation and hygiene of keeping rooms, processing equipments, produce surfaces, and washing water. The sanitation of fresh produce, occasionally followed by fungicidal treatment, is crucial in reducing up to 50% or more decay losses.[181] They are extensively used for lowering surface contamination, especially of pathogens concerned with human health.[182] In contrast to fungicide use, sanitation causes fast mortality of pathogens without depositing any residue on fruit surfaces. The most common sanitizers that have been employed for reducing the inoculums of post-harvest fruit associated pathogenic *Penicillium* species are described in the following sections.

Chlorine compounds and ozone

The dissolved solution of chlorine (Cl_2) or hypochlorite (OCl) is the most widely used aqueous sanitizer for decontamination purpose in the purification of drinking water and food industry on a commercial scale.[183] Their ability of rapidly killing pathogen propagules is valuable in preventing the pathogens spread from infected fruits to healthy. The chlorine-containing compounds have found effective against *Penicillium* mold associated with fruit decay. For example, the free solution of chlorine (200 mg L^{-1}) inactivated about 95% conidia of the citrus green mold pathogen, *P. digitatum*. The time (in seconds) required for conidial inactivation was 13.2, 19.1, 29.4, and 88.4 sec at pH 7, 8, 9, or 10, respectively.[184] The efficacy of chlorine dioxide (ClO_2) gas in preventing harmful fungal and bacterial growth on fresh produce has been demonstrated.[185,186] In most of studies, control efficacy of these compounds had been shownd on the human pathogens. The successful use of both Cl_2 and ClO_2 at almost similar concentrations killed conidial growth of numerous pathogens such as *P. expansum* and *Mucor piriformis*[187], and *P. expansum, Botrytis cinerea, Cryptosporiopsis perennans*, and *M. piriformis*, occurring in the storage and packinghouses of apple and pear fruits.[188] The tolerance level of fungi to chlorine compounds is often high than for bacteria and viruses. During commodities storage, chlorine gases are applied experimentally either for a short period or incessantly to

Table 3. Some examples of plant-derived antifungal botanicals used for managing the *Penicillium* induced infection in different fruits.

Target pathogen(s)	Disease/decay	Host	Antifungal constituents	Treatments/ results/remarks	Source (s)
Penicillium spp.	*Penicillium* decay	Apple	Essential oils	Treatments of fruits with the essential oils of oregano, clove, and cinnamon successfully retarded fungal growth	[150]
Penicillium digitatum, Penicillium italicum	Green and blue mold	Citrus	Essential oils	The antifungal activity of thyme and cinnamon EOs considerably controlled fungal green and blue rotting mold on harvested apples	[172 173]
Penicillium adametzioides	*Penicillium* decay	Pomegranate	Phenolic compounds	Treatment of fruits with the phenolic compounds of olive-mill wastewater (4mg mL−1 and 8 mg mL−1) minimized the fungal decay incidence by 30% and 15%, respectively	[47]
P. expansum	Blue mold	Apple	Solvent extracts	The methanolic extracts of Clove, Dodonaea, Garlic, showed antifungal activity against blue rot pathogen	[174]
P. expansum	Blue mold	Apple	Crude extracts and essential oils	20 different plants leaf extracts and 3 essential oils were screened for their antifungal potential. Among them, dip treatment of infected fruits with the leaf extract of neem (*Azadirachta indica)* significantly reduced *Penicllium* rot.	[175]
Penicillium oxalicum and other decay fungi	*Penicillium* and other fungal rot	Cassava	Solvent and aqueous extracts	Antifungal assay of water and ethanolic extracts of *A. indica* leaves and *Aframomum melegueta* seeds revealed that the plant extracts of *A. indica* was more fungicidal than *A. melegueta* and prevented post-harvest cassava spoilage caused by pathogenic fungi	[176]
P. digitatum, P. italicum	Green and blue mold	Kinnow mandarin	Aqueous extracts	Among the aquous extracts of *Aloe vera*, Eucalyptus and Ocimum botanicals, extract of *A. vera* was found to most effective in the controlling blue and green mold pathogen of fruits under in vitro conditions.	[177]
P. digitatum, P. italicum	Green and blue mold	-	Extract containing caffeic acid derivatives and flavonoids	Plant extract obtained from the herb (*Sanguisorba minor* and *Plantago lanceolata*) significantly inhibited the pathogen spore germination and germ tube elongation. Further, phenolic compounds impeded the growth of pathogen by about 92%, after 25th day storage.	[159]
P. digitatum P. glabrum	Penicillium decay pathogens	-	Extract of soyaben flour containing β-conglycinin and glycinin	soy protein fractions (@50-3,000 mgL−1]) of soybean four extracts significantly inhibited pathogen *in vitro* and full germination inhibition was noticed when it was used at a concentration of 2000 mgL−1]	[178]
P. digitatum	Green mold		Essential oil, β-caryophyllene and eugenol	Antifungal botanicals of *Eugenia caryophyllata* considerably reduced green mold pathogen growth	[179]
P. digitatum	Green mold		Essential oil, thymol, *p*-cymene, carvacrol, and δ-terpinene	Thymus derived antimicrobial compounds was found effective in checking the proliferation of pathogen growth	[180]

products for preventing microbial spoilage. In Israel, the commercial MegAir1 technology, being used for the continuous on-site production of both Cl_2 and ClO_2, is deployed for the safe storage of freshly harvested fruits.[189] The presence of ClO_2 residues is found negligible and comparatively non-persistent in treated fruit.[186–190] For example, numerous fruits such as apples, tomatoes, strawberries, oranges, and cantaloupe treated with chlorine compounds (@ 0.1–5.0 mg L^{-1} for 10–30 min) were devoid of any residue, and if present, it was reduced noticeably after 14 days.

Ozone (O_3) is another most potent biocidal compound. Historically, it has been utilized for decontamination of wastewater, bottled drinking water, aquaculture, and swimming pool.[191] Its germicidal property is reliant on the concentration used, temperature, exposure time, humidity, and the residing substrate. However, short half-life, poor diffusion, partial water solubility, rapid decomposition, and high operating costs make ozone use often challenging.[191,192] Many literature reviews related to ozone application on fresh produce of fruit and vegetables have been published.[193–195] In post-harvest *Penicillium* decay control, ozone gas is effective at both lower and higher concentrations. At low concentrations, it hampers the pathogens hyphal growth, though, infrequently can activate conidial production.[196] The periodic exposure of UV-generated ozone to the conidia of *P. digitatum, P. expansum, P. italicum, Alternaria alternate, Aspergillus flavus*, and *Aspergillus niger* in a humid atmosphere (during storage of 100 days at 2°C of air or 0.15 mL L^{-1} ozone) caused 95% conidial mortality after 2–3 months of storage.[197] Indirectly, ozone gas confers some benefits to host fruits through the; (1) retardation of fruit senescence driven by reduction in ethylene, (2) minimizing the air-borne inoculums via conidial suppression, and (3) elicitation of host resistance against pathogen.[198,199] Also, it prolongs shelf life of various fruits such as grapes, raspberries, and other berries without any injury.[18] At higher concentrations, ozone gas effectively inactivates pathogens conidia. The exposure of pathogens such as *P. italicum, P. digitatum*, and *B. cinerea* to different ozone concentrations (at 25°C and 95% RH) for 1 h reduced conidial germination by almost 99%.[200] However, the toxic effect of ozone on conidial growth was reduced significantly with the decrease in RH.

Ethyl alcohol and hydrogen peroxide

Ethyl alcohol, two carbon-containing alcohols, is mostly used for microbial decontamination in the medicinal field.[201] It deactivates microbial metabolism through inducing cellular membrane damages and protein denaturation. The negative effect of ethanol on fungi includes temperature-dependent inhibition of conidial germination.[202] The first study on the potential ethanol use for surface disinfestation of freshly harvested lemon fruit was done for the control of green mold disease, inflicted by P. *digitatum*; however, high temperature (44°C) was needed for complete prevention of fungal rot using higher (20% or 40%) concentrations of ethanol.[203] Likewise, ethanol vapors also suppressed fungal growth during storage of fruits, where it successfully impeded green and blue mold decay of orange fruits caused by *P. digitatum* and *P. italicum*. Apart from this, these compounds were also effective in managing other fungal decay on harvested fruits during post-harvest handling and storage phase.[204] Hydrogen peroxide (H_2O_2), recognized as a GRAS compound, is toxic to microbial cells due to strong oxidizing power, generation of ROS, and OH radicals, which inactivate cellular respiratory enzymes, damages nucleic acid and triggers several physiological, biochemical, and molecular response within cells.[205,206] Certain *in vivo* and *in vitro* experiments have proved its antifungal activity against *Penicillium* spoilage of various horticultural produce. For example, sequential application of NaOCl and H_2O_2 in combination with cupric salt suppressed mycelia growth and conidia germination of *P. expansum* and *P. digitatum* infecting apple and lemons.[207] This treatment caused disorganization in the fungal conidia and rigorous cellular damage. In another study, Cerioni et al.[208] reported that mycelium of *P. digitatum* was more susceptible than its conidia to the H_2O_2 treatment when applied relatively at higher concentrations. Furthermore, the proteomic studies revealed severe oxidative damages to the mitochondria membrane proteins and cellular respiratory system due to H_2O_2 treatment. The pH and exposure time-dependent conidial inhibition were reported in *P. digitatum*, whereby, inhibition was high when exposed to low pH and more time of H_2O_2 treatment.[209] Hydrogen peroxide when combined with other food-grade compounds also controlled *Penicillium* spoilage incidence. Its combined application with as sodium bicarbonate, potassium sorbate, or potassium phosphate effectively managed the blue mold decay of lemons.[210] Though H_2O_2 is effective for *Penicillium* decay control, sometimes, it may become phytotoxic and can incite color bleaching on fresh tissue, as same reported in table grapes (green to yellow discoloration) and lemons (red to bronze discoloration).[18]

Organic acids

The biocidal property of some food-grade organic acids (acetic, citric, oxalic, malic, propionic, and tartaric acid) projects their use successful in post-harvest control of *Penicillium* and other rot-inducing fungi. In food matrices, they can perform the role of antimicrobial compounds as well as antioxidants that help in preventing color, flavor, and textural changes. Besides these, some plant-based organic acids such as salicylic acid and jasmonic acid stimulate host defense systems against *Penicillium* and other rotting fungi.[211,212] The acetic acid (4–6%) containing vinegar vapors retarded conidial germination of pathogen *P. expansum, M. fructicola*, and *B. cinerea* causing spoilage in apples, stone fruit, and strawberries, respectively.[213] Among the various combination of treatment, apple fruits when treated with hot acetic acid solutions (1%, 2%, and 3% for 1, 2 and 3 min, respectively) at 50°C significantly reduced fungal decay, more particularly, 3% acetic acid treatment for 2 min and 2% acetic acid treatment for 3 min was the most efficient combination.[214] Fumigation using acetic acid or its combine application with heat treatment[215] significantly reduces the incidence of *Penicillium* decay on table grapes and mandarin fruits.

Another organic acid, oxalic acid, when applied during pre-harvest stage improved ascorbic acid content, decreased fruit firmness and further, reduced blue mold incidence and lesion diameter of *P. expansum* on kiwi fruits.[216] Proteomic analysis of jujube fruits, following application of oxalic acid, revealed augmented fruit resistance against blue mold pathogen, *P. expansum* and also adversely affected ethylene metabolism that delayed senescence.[217] Cinnamic acid obtained from cinnamon bark exhibited biocidal action against *P. expansum* and other decay pathogens such as *B. cinerea* and *A. niger*.[218] The disintegration of plasma membrane integrity and generation of toxic ROS was the principal modes by which cinnamic acid hampered the fungal growth.[219] In a similar way, propionic, sorbic, decanoic, benzoic, and citric when used at different concentrations were successful in the averting growth of *Penicillium commune* induced decay on litchi fruits and against other pathogenic fungi including *P. digitatum, P. italicum*, and *Geotrichum candidum*.[220]

Electrolyzed water

More recently, the use of electrolyzed water (EW) as sanitizer has become more popular in the food supply chain.[221] Their main applications are disinfection of processing utensils, meat and products, cutting boards, and in livestock management, and in latest times, sanitation of water chiefly used for fresh fruit and vegetable washing.[222,223] The use of EW for managing food-borne diseases and the growth of spoilage microbes in processed vegetables were also reported.[224] The harmful effect of EW in combination sodium bicarbonate (1.25%) on inhibition of *Penicillium* spp. growth has been documented by Fallanaj et al.[223] Authors demonstrated that population of *Penicillium* spp. was reduced by 93% in citrus wash water after 1 hr of the beginning of the electrolysis process. The same results were obtained only after 7 hr when electrolyzed tap water without sodium bicarbonate was used. Further, the electrolyzed sodium bicarbonate solution completely stopped the growth of *Penicillium* spp., and hence, no decay development was noticed. The fungicidal actions of EW are not entirely known,thoughsome proposed mechanisms for its antimicrobial action include; (1) cellular oxidative damage by the oxidants produced[225] (2) up-regulation and activation of host defense genes coding phenylalanine ammonia-lyase, chitinase, and peroxidase etc.[226], (3) antimicrobial action is also due to the joint action of oxidative radicals, pH, free chlorine, and other unknown active compounds of EW.[227] Examples of different GRAS chemicals and disinfecting agents used for management of *Penicillium* induced infection in different fruits are given in Table 4.

Modern physical approaches for managing *Penicillium* and related fungal infections in the harvested produce

Cold storage and its impacts on fruit spoiling pathogens

Cold storage is the most commonly used physical method for minimizing the negative impacts of biotic and abiotic stresses on freshly harvested produce. The low-temperature storage is effective in prolonging shelf life along with retention of nutritional and sensory attributes of fruits and vegetables.[237] It not only controls these stresses but also ensures safety and quality fresh produce.[238] Low temperature brings down the metabolism rate, especially respiration of commodities and enhances their shelf life. Low temperature, like sanitizers, does not have direct biocidal action but contributes significantly in slowing the growth of microbes through freezing their enzymatic activities. Further, cold storage also maintains the host resistance to storage pathogen via reduced host metabolism and therefore minimize the activities of spoilage-causing pathogens. With the exception of psychrophile, the growth of other microbes, commonly occurring at surfaces and epidermal areas of fruits are generally stopped at a low-temperature range (4–11°C). The lowest sustained temperatures for growth and development of several fungi are in the region of 0°C, although certain rotting fungi are capable to grow even at freezing temperature. The

Table 4. Examples of food-grade chemicals, and disinfecting agents used for management of *Penicillium* induced infection in different fruits.

Target pathogen(s)	Disease/decay	Host	Treatments/ results/remarks	Source (s)
Food-grade chemicals				
P. digitatum, P. italicum	Blue and green mold	Citrus	Potassium sorbate	[228]
P. digitatum, P. italicum	Green and blue mold	Citrus	Sodium ethyl paraben	[229]
P. digitatum	Green mold	Citrus	Sodium bicarbonate	[230]
P. digitatum, P. italicum	Green and blue mold	Lemon	Potassium sorbate	[231]
Ozone treatment				
P. digitatum	Naturally occurring decay	Tangerine	Showed fungicidal property against pathogen	[232]
P. digitatum, P. expansum, P. italicum, A. alternate, Aspergillus flavus, A. niger	*Penicillium* and other fungus induced decay	-	Ozone treatment at 2°C of air with or 0.15 mL L−1 in humid storage resulted in 95% conidial mortality after a 2–3 months of storage	[197]
P. italicum, P. digitatum, and *B. cinerea*,	*Penicillium* and other fungus induced decay	-	Different concentrations of ozone (at 25°C and 95% RH) for 1 h reduced conidial germination by almost 99%	[200]
Hydrogen peroxide				
P. expansum	Blue mold	Apple	Suppressed mycelia growth and conidia germination	[233]
P. digitatum	Green mold	Lemon	Suppressed mycelia growth and conidia germination	[208]
P. expansum	Blue mold		Caused oxidative damages to membrane proteins of mitochondria and cellular respiratory system	[234]
P. italicum	Blue mold	Lemon	Chronologically treatment of NaOCl (200 mg L−1 for 2 min), followed by H_2O_2 (20 g L−1for a second), in the presence of cupric sulfate reduced 50% incidence of green mold disease	[235]
Electrolyzed water				
Penicillium spp.	*Penicillium* decay	Citrus	EW when used in combination sodium bicarbonate (1.25%) inhibited pathogen growth by 93%	[223]
P. digitatum	Green mold	Tangerine	The EW has detrimental impacts on the decay pathogen	[236]
Organic acids				
P. expansum	Blue mold	Apple	4–6% concentration of acetic acid effectively retarded pathogens conidial germination	[213]
P. expansum	Blue mold	Kiwifruit	Preharvest use of oxalic acid, improved ascorbic acid content, decreased fruit firmness, blue mold incidence, and disease lesion diameter on fruits	[216]
P. expansum, B. cinerea, A. niger	decay pathogens		Cinnamic acid of cinnamon bark exhibited strong antimicrobial activity against decay pathogens	[218]

lowest recorded temperatures for the sustenance of certain fungal species are −4°C for *Cladosporium herbarum*, −3°C for *P. expansum* and A. *alternate*, and −2°C for *B. cinerea*. Though effective in microbial growth retardation, certain fruits and vegetables held in cold storage may experience chilling injuries, which are further dependent on their genetic makeup and background, crop and cultivar, crop location, physiological status during harvesting, and exposure time.[5]

Controlled and modified atmosphere storage

Controlled atmosphere (CA) storage has exact control of CO_2 and O_2 level and ethylene produced during storage, while, modified atmosphere (MA) storage implies any kind of synthetic atmosphere, without control of its constituent gases, especially oxygen and carbon dioxide[239,240] The altered storage gas compositions have a significant impact on the physiology and metabolism of harvested commodities and keeping quality of produce.[241] During CA storage, it has favorable effects on the stored produce and adverse impacts on the fungal pathogen affecting commodities. Also, it delays the process of ripening and senescence and postpones the time at which fruits may become susceptible to the fungal attack and decay development. Simultaneously, it reduces the growth, metabolism, and pathogenesis-related activities of decay inflicting fungal pathogens. However, the lower concentration of O_2 (less than 1%) is often essential to cause a considerable inhibition of spore germination, pathogens growth, and sporulation.

In regards to post-harvest disease control, the importance of CA in the effective reduction of *P. expansum*, an etiological agent of blue mold decay in apple fruits has been shown. Considerably, apples artificially inoculated with the pathogen, *P. expansum* and subsequently, held at 0°C under CA conditions of 3% O_2 and 2% CO_2 were with less incidence of blue rotting, as compared to normal cold-stored fruits.[242] The results of a study by Conway et al.[243] demonstrated the combined action of microbial antagonist and sodium bicarbonate on the *P. expansum*, blue mold pathogen of apple stored under the controlled storage (containing 1.4 kPa O_2 and 3 kPa CO_2) for a period of 16 weeks at 1°C. This treatment effectively improved the viable population of antagonists that resulted in the successful elimination of fungus-induced decay under CA storage atmosphere. MA is usually achieved by sealing definite commodities in a polymer containing semi-permeable packaging film. This process increases CO_2 level and decreases O_2 level in the packed film and reduces the respiration rate from the stored commodities,[244,245,] which further augment the post-harvest life of produce.[5] The increased level of CO2 is fungistatic and reduces the development of decay pathogen in sealed packaging materials.

Hot water and hot air treatments

Hot water treatment (HWT) is a non-traditional, energy-efficient, safer and low-cost technique for post-harvest decay management.[246,247,] It is more effective due to great efficient heat transfer-mediated impacts on pathogen and surface microorganisms. HWT, in particular, is mostly used in managing pests of tropical and subtropical fruit crops, which have phytosanitary and quarantine regulatory importance. HWTs is generally applied either as hot water dips, brushing, or/and rinsing. In post-harvest disease control, fruits are successfully treated using HWT typically involving hot water with temperature ranging in between 45°C and 60°C and time-varying from few seconds to 20 min.[242] For some post-harvest pathogens, the duration of exposure has a direct influence on the success of treatment. For example, HWT was unable to manage infection of *P. expansum* or *P. digitatum*, when fruits were treated after 2 h of pathogen inoculation, contrary; HWT of fruits after 24 h of pathogens inoculation was effective in reducing the incidence of blue or green mold incidence.[248,249] Most studies have demonstrated the effectiveness of HWT as curative measures of post-harvest disease prevention, but, its use as preventive control measures has been less studied. Some latest reports illustrated that this treatment, when applied 1 or 4 h before pathogen inoculation, resulted in 30% decline of apple blue mold incidence, probably by stimulating defense responses in fruit.[250] HWT as a preventive measure is also effective in reducing disease development and improving skin color, as observed in mango. The mango transcriptomic analysis of hot water treated mango fruit and its peel samples revealed a differential level of gene expression and host phenotypic response.[251] The genes involved in the abiotic stress responses, host resistance to the pathogen, and carbohydrates and flavonoid metabolism were highly upregulated while genes linked with the chlorophyll degradation and photosynthesis, were down-regulated. The effective use of other HWT methods such as hot water dipping and hot water rinse brushing is also demonstrated in the successful management of post-harvest penicillium spoilage occurring in the pear, orange, lemons, grapefruits, and tangerine.[252–254] Usually, improperly hot water treated fresh commodities can experience internal and external injuries including symptoms of as skin browning, pitting, colored spots, and browning.[255]

Hot air treatment employs longer exposure (several hours or days) of fruits in a heated air atmosphere having temperature and RH of more than 30°C and 90%, respectively. The time and temperature of treatment depend on the incidence and severity of pathogen damage. This method has a less success rate as compared to other methods. Its effectiveness in decay control can be enhanced by its integrative use with antagonistic microbes, food-grade chemicals, modified atmosphere, or combination of these. Hot air treatment in the successful control of *Penicillium* decay incidence on several harvested fruits has been reported. For example, a long hot air treatment at 33°C for 65 h successfully managed both blue and green mold disease, inflicted by *P. italicum* and *P. digitatum* and, respectively, on lemon and orange fruits.[242] As reported by other researchers, the similar level of *Penicillium* and other fungus-induced spoilage control in various fruits and their different varieties by hot air treatments have been achieved.[256]

Cold plasma technology in preventing post-harvest fungal spoilage

Plasma is a partly neutral ionized gas and considered as the fourth state of matter, following solids, liquids, and gases. Cold plasma (CP) is produced by passing an electric current to a gaseous mixture and it usually contains nitrogen, helium, argon, air or oxygen.[17] In general, the key components of CP include a mix of atoms, charged particles, excited molecules, and reactive species of oxygen and nitrogen (RONS) such as superoxide, ozone, hydroxyl, hydroperoxyl, nitric oxide, nitrogen dioxide, dinitrogen pentoxide, and UV photons.[257] These reactive ions are generally lethal to the pathogen growth and metabolism and do not have any concerns of harmful residues or by-products generation in the environment.

CP is portrayed as a method for the successful decontamination of pathogenic microbes in a chemical and residue-free way. The effective use of CP for bacterial decontamination of various agro-horticultural commodities such as fresh fruit and vegetables, nuts, seeds and spices, etc. has been reported.[258–262] Although, most of the studies on the use of CP is concerned with surface bacterial decontamination, however, report of some latest studies has demonstrated its strong fungicidal actions against many fungal pathogens, hence, signifying its potential use in managing decay. The surface washing, from the fruits of red grapes, strawberries, and cherries, stored in pack-house, when disinfected with CP for 7.5 min, successfully reduced viable spore's count of several fungal pathogens including *P. italicum, Aspergillus niger*, and *A. alternate*.[263] Won et al.[264] demonstrated that effective surface decontamination of Satsuma mandarins' fruits with CP for 10 min reduced pathogen spores and further caused 84% reduction in the incidence of blue mold disease, inflicted by pathogen *P. italicum*. In another study, cold plasma treatment was effective in reducing the inoculums of post-harvest green mold pathogen infecting lemon fruits. Authors observed that fruit treated with 10 min of CP were free of disease symptoms and nearly 100% inactivation of pathogens spore was noticed.[265]

The precise antimicrobial mode of CP is vague,though prevention of pathogen growth and stimulation ofdefense systems in host tissue is believed as the main reasons for its antifungal activity. Many cellular components of pathogens such as cell wall, cell membrane, DNA, protein, enzymes, and fatty acids are functionally inactivated by the actions of cold plasma treatments, which results in the decontamination of harmful microbes from the foodstuffs. In general, some reported damaging effects of CP treatments on pathogens included: (1) alteration in cell membrane/cell wall permeability, (2) destruction and deformation in cell membrane, (3) protoplasmic leakage of cytoplasmic contents, and (4) serious damage to cellular proteins, and DNA molecule through generation of RONS and possibly by UV photons.[266,267] With microscopic analysis, Ye et al.[268] (2012) found that CP treatment of blue mold pathogen, *P. expansum*, distorted the protoplasmic membrane, reduced cytoplasmic volume, vacuolar expansion, and completely disrupted cellular fluids. They also observed invagination and lysis of cell membrane, followed by external leakage of the protoplasmic contents. The proposed mechanisms of cold plasma actions implicated in functional deactivation of microbial cell are schematically represented (Fig. 2)

Pulsed light technology

Pulsed light (PL) processing is nonthermal technology primarily being employed for microbial decontamination of various foodstuffs such as fresh fruits and vegetables, fruit juices, and meat products. PL processing, an alternative technology to UV light, utilizes high-intensity light pulse treatment for a small duration of time.[271] The lights used in PL processing have a wide wavelength range (200–1100 nm), comprising ultraviolet range (200–400 nm), visible range (400–700 nm), and near-infrared range covering 700–1100 nm.[272] The potential applications of PL technology in food processing are for rapid microbial disinfection of various commodities such as fresh fruits and vegetables, meat slices or hard cheeses, etc., where surface contamination with harmful microbes is a major concern. The effectiveness of PL treatments in microbial deactivation depends upon microbial light absorption and matrix properties.

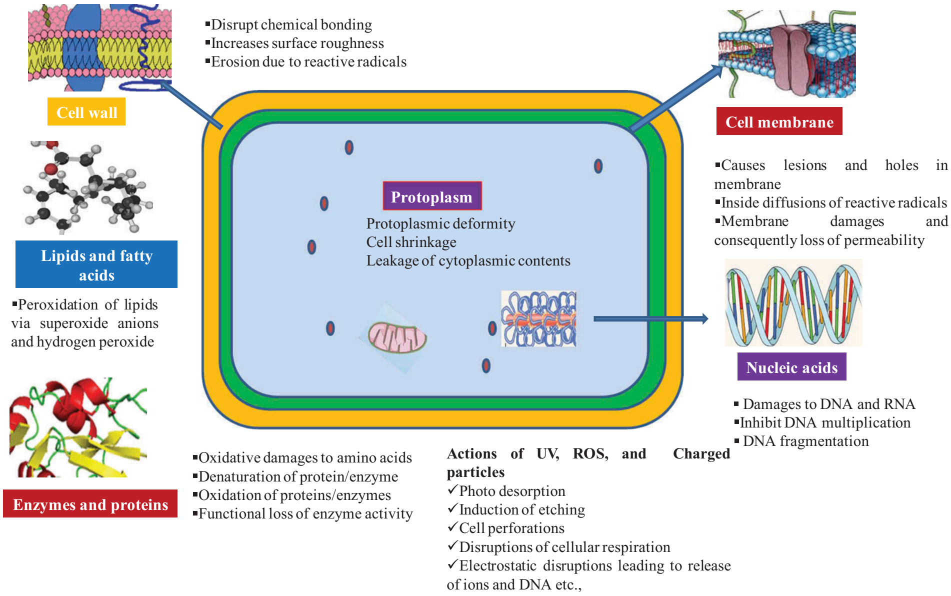

Figure 2. A schematic diagram demonstrating typical mechanisms of cold plasma actions implicated in functional inactivation of microbial cell, thereby resulting in the decontamination of harmful microbes from the foodstuffs. This figure is adopted in modified form from Misra and Jo[269] and Schluter and Frohling.[270]

PL treatments principally use ultraviolet (UV) rich light region for the killing and effective inactivation of harmful microorganisms from solid and liquid foods. Furthermore, the combined actions of both visible and infrared regions of PL also contribute to the destructive and damaging effects on the harmful microbes.[272] Its antimicrobial activities are mainly due to structural changes in the DNA and proteins caused by absorption UV radiation in the conjugated carbon-carbon double bonds in nucleic acids and proteins.[273–275]

With regards to spoilage fungi control, the PL treatment has detrimental effects on the growth and development of pathogenic *Penicillium* species. The application of PL was effective in reducing the spore count of *Penicillium frequentans* on the surface of apples, pears, and fruits. Similarly, this treatment also caused reduction in the CFU count of dry spores of *P. digitatum*, from 10^6–10^4, on the "Valencia" variety of oranges.[276] In case of liquids, PL treatment of apple juice at a depth of 6 to 10 mm drastically inactivated *P. expansum* and significantly reduced colony-forming units (CFU)/ml^{-1} from 3.21 to 1.58 log.[277] Inactivating effect was greatly depended on the microbial load that is 1.30 and 3.2 log reduction for 3×10^5 and 2.3×10^4 CFU ml^{-1}, respectively.[277] This technology is capable of reducing risk from foodborne human pathogens, extending shelf life of the product and improved economics during the food supply chain.[278] However, current literature on PL application for disinfestations of fruits and vegetables is scarce; hence more additional scientific data are indispensable to appraise the appropriateness of this technology in controlling lethal microbes and fungal pathogens of harvested commodities.

Conclusions

Post-production wastage of fresh produce due to harmful fungi, more particularly by *Penicillium* spp., can be huge, hence, requires global attention for reducing losses caused by them. The occurrence of *Penicillium* spp., in certain foods, is often harmful, as, besides food wastage, they are also involved in the production of mycotoxins, alkaloids, and allergens, all of which have negative impacts on human health. The detrimental environmental impacts and regulatory constraints associated with the synthetic chemicals mediated disease suppression have allowed the shift from an era of chemistry to an era of biology.[279,280] Among the proposed and emerging alternatives, use of biocontrol organism, plant-derived natural products; GRAS categorized chemicals and latest emerging physical approaches are gaining impetus in managing key mold pathogens. The simplicity of genome sequencing and information obtained from the genomics, transcriptomics, proteomics, and metabolomics studies have demonstrated huge perspective for the formulation and development of novel "biological" based commercial technologies. In regards to postharvest disease control, we have shifted from simpler to the complex alternative for managing decay in an economically and dependable way. Here, one thing is to note that a single methodological intervention is often not sufficient; henceforth, multiple interventions, at different points of the disease development process, are required to achieve almost a complete control of the post-harvest disease. The non-fungicide-based promising and eco-friendly approaches, when used individually or in combination can affect a successful control of *Penicillium* and other decay pathogens and will ensure safety, quality, and shelf life of produce during post-harvest handling, storage, shipment, and distribution.

Conflict of interest

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References

[1] Xu, Y.; Charles, M. T.; Luo, Z.; Mimee, B.; Tong, Z.; Veronneau, P.-Y.; Roussel, D.; Rolland, D. UV-C Priming of Strawberry Leaves against Subsequent *Mycosphaerella Fragariae* Infection Involves the Action of ROS, Plant Hormones and Terpenes. *Plant Cell Environ.* **2019**, *42*, 815–831. DOI: 10.1111/pce.13491.

[2] OECD. *Market and Trade Impacts of Food Loss and Waste Reduction*; Paris, France: Organization for Economic Cooperation and Development, 2014. accessed Nov 20, 2018)..

[3] Dukare, A. S.; Paul, S.; Nambi, V. E.; Gupta, R. K.; Singh, R.; Sharma, K.; Vishwakarma, R. K. Exploitation of Microbial Antagonists for the Control of Postharvest Diseases of Fruits: A Review. *Crit. Rev. Food Sci. Nutr.* **2018**, *58*(2), 1–16. DOI: 10.1080/10408398.2014.971353.

[4] Droby, S.; Chalutz, E.; Wilson, C. L.; Wisniewski, M. E. Biological Control of Postharvest Diseases: A Promising Alternative to the Use of Synthetic Fungicides. *Phytoparasitica*. **1992**, *20*, 1495–1503. DOI: 10.1007/BF02980427.

[5] Barkai-Golan, R. *Postharvest Diseases of Fruit and Vegetables: Development and Control*; Elsevier Sciences: Amsterdam, The Netherlands, 2001.

[6] Visagie, C. M.; Houbraken, J.; Frisvad, J. C.; Hong S. B.; Klaassen C. H. W.; Perrone G.; Seifert K. A.; Varga J.; Yaguchi T.; Samson R. A. Identification and Nomenclature of the Genus Penicillium. *Stud. Mycol.* **2014a**, *78*, 343–371. DOI: 10.1016/j.simyco.2014.09.001.

[7] Samson, R. A.; Pitt, J. I.; Eds.; *Integration of Modern Taxonomic Methods in Penicillium and Aspergillus Classification*; Harwood Academic Publishers: Amsterdam, 2000; pp 179–188.

[8] Marcet-Houben, M.; Ballester, A. R.; De la Fuente, B.; Harries, E.; Marcos, J. F.; González-Candelas, L.; Gabaldón, T. Genome Sequence of the Necrotrophic Fungus *Penicillium Digitatum*, the Main Postharvest Pathogen of Citrus. *BMC Genom.* **2012**, *13*, 646. DOI: 10.1186/1471-2164-13-646.

[9] Louw, J. P.; Korsten, L. Pathogenicity and Host Susceptibility of Penicillium Spp. On Citrus. *Plant Dis.* **2015**, *99*, 21–30. DOI: 10.1094/PDIS-02-14-0122-RE.

[10] Wallace, R. L.; Hirkala, D. L.; Nelson, L. M. Postharvest Biological Control of Blue Mold of Apple by *Pseudomonas Fluorescens* during Commercial Storage and Potential Modes of Action. *Postharvest Biol. Tec.* **2017**, *133*, 1–11. DOI: 10.1016/j.postharvbio.2017.07.003.

[11] Prencipe, S.; Siciliano, I.; Gatti, C.; Garibaldi, A.; Gullino, M. L.; Botta, R.; Spadaro, D. Several Species of Penicillium Isolated from Chestnut Flour Processing are Pathogenic on Fresh Chestnuts and Produce Mycotoxins. *Food Microbiol.* **2018**, *76*, 396–404. DOI: 10.1016/j.fm.2018.07.003.

[12] Kinay, P.; Mansour, M. F.; Gabler, F. M.; Margosan, D. A.; Smilanick, J. L. Characterization of Fungicide-resistant Isolates of *Penicillium Digitatum* Collected in California. *Crop Prot.* **2007**, *26*, 647–656. DOI: 10.1016/j.cropro.2006.06.002.

[13] Droby, S. Improving Quality and Safety of Fresh Fruit and Vegetables after Harvest by the Use of Biocontrol Agents and Natural Materials. *Acta Hortic.* **2006**, *709*, 45–51. DOI: 10.17660/ActaHortic.2006.709.5.

[14] Liu, J.; Sui, Y.; Wisniewski, M.; Droby, S.; Liu, Y. Review: Utilization of Antagonistic Yeasts to Manage Postharvest Fungal Diseases of Fruit. *Int. J. Food Microbiol.* **2013**, *167*, 153–160. DOI: 10.1016/j.ijfoodmicro.2013.09.004.

[15] Bonaterra, A.; Badosa, E.; Cabrefiga, J.; Francés, J.; Montesinos, E. Prospects and Limitations of Microbial Pesticides for Control of Bacterial and Fungal Pomefruit Tree Diseases. *Trees*. **2012**, *26*, 215–226. DOI: 10.1007/s00468-011-0626-y.

[16] Ciocan, I. D.; Băra, I. Plant Products as Antimicrobial Agents.*Universitatii Ale Ştiinţifice Analele Al I Cuza*. **2007**, *8*, 151–156.

[17] Herceg, Z.; Režek Jambrak, A.; Vukušić, T.; Stulić, V.; Stanzer, D.; Milošević, S. The Effect of High-power Ultrasound and Gas Phase Plasma Treatment on *Aspergillus* Spp. And *Penicillium* Spp. Count in Pure Culture. *J. Appl. Microbiol.* **2015**, *118*, 132–141. DOI: 10.1111/jam.12692.

[18] Feliziani, E.; Lichter, A.; Smilanick, J. L.; Ippolito, L. Disinfecting Agents for Controlling Fruit and Vegetable Diseases after Harvest. *Postharvest Biol. Tec.* **2016**, *122*, 53–69. DOI: 10.1016/j.postharvbio.2016.04.016.

[19] Gómez-Sanchis, J.; Gómez-Chova, L.; Aleixos, N.; Camps-Valls, G.; Montesino- Herrero, C.; Moltó, E.; Blasco, J. Hyperspectral System for Early Detection of Rottenness Caused by *Penicillium Digitatum* in Mandarins. *J. Food Eng.* **2008**, *89*(1), 80–86. DOI: 10.1016/j.jfoodeng.2008.04.009.

[20] G´omez-Sanchis, J.; Blasco, J.; Soria-Olivas, E.; Lorente, D.; Escandell-Montero, P.; Martınez-Martınez, J. M.; Martınez-Sober, M.; Aleixos, N. Hyperspectral LCTF-based System for Classification of Decay in Mandarins Caused by *Penicillium Digitatum* and *Penicillium Italicum* Using the Most Relevant Bands and Non-linear Classifiers. *Postharvest Biol. Tec.* **2013**, *82*, 76–86. DOI: 10.1016/j.postharvbio.2013.02.011.

[21] Li, J.; Huang, W.; Tian, X.; Wang, C.; Fan, S.; Zhao, C. Fast Detection and Visualization of Early Decay in Citrus Using Vis-NIR Hyperspectral Imaging. *Comput. Electron. Agr.* **2016**, *127*, 582–592. DOI: 10.1016/j.compag.2016.07.016.
[22] Wisniewski, M.; Droby, S.; Norelli, J.; Liu, J.; Schena, L. Alternative Management Technologies for Postharvest Disease Control, the Journey from Simplicity to Complexity. *Postharvest Biol. Technol.* **2016**, *122*, 3–10. DOI: 10.1016/j.postharvbio.2016.05.012.
[23] Atlas, R. M.; Bartha, R. *Microbial Ecology Fundamentals and Applications*, 4th ed.; Benjamin/ Cummings Science Publishing: California, 1998; pp 175–176.
[24] Korsten, L. Advances in Control of Postharvest Diseases in Tropical Fruit Produce. *Int. J. Postharvest Technol. Innov.* **2006**, *1*, 48–61. DOI: 10.1504/IJPTI.2006.009181.
[25] Neri, F.; Mari, M.; Menniti, A. M.; Brigati, S.; Bertolini, P. Control of *Penicillium Expansum* in Pears and Apples by Trans-2-hexanal Vapours. *Postharvest Biol. Tec.* **2006**, *41*, 101–108. DOI: 10.1016/j.postharvbio.2006.02.005.
[26] Whitfield, F. B. Microbiology of Food Taints. *Int. J. Food Sci. Technol.* **1998**, *33*, 31–51. DOI: 10.1046/j.1365-2621.1998.00156.x.
[27] Eckert, J. W.; Eaks, I. L. Postharvest Disorders an D Diseases of Citrus Fruits. In *The Citrus Industry*; Reuter, W., Calavan, E.C., Carman, G.E., Eds.; Univ. Calif. Press: Berkeley, USA, 1989; Vol. 5, pp 179–260.
[28] Farr, D. F.; Rossman, A. Y. Fungal Databases, Systematic Mycology and Microbiology Laboratory, ARS, **2016**. USDA. http://nt.ars-grin.gov/fungaldatabases/.
[29] Vilanova, L.; Viñas, I.; Torres, R.; Usall, J.; Buron-Moles, G.; Teixidó, N. Increasing Maturity Reduces Wound Response and Lignification Processes against *Penicillium Expansum* (Pathogen) and *Penicillium Digitatum* (Non-host Pathogen) Infection in Apples. *Postharvest Biol. Technol.* **2014**, *88*, 54–60. DOI: 10.1016/j.postharvbio.2013.09.009.
[30] Hernández-Montiel, L. G.; Ochoa, J. L.; Troyo-Diéguez, E.; Larralde-Corona, C. P. Biocontrol of Postharvest Blue Mold (*Penicillium italicum*Wehmer) on Mexican Lime by Marine and Citrus *Debaryomyces Hansenii* Isolates. *Postharvest Biol. Tec.* **2010**, *56*, 181–187. DOI: 10.1016/j.postharvbio.2009.12.010.
[31] Niu, Y.; Yuan, Y.; Mao, J.; Yang, Z.; Cao, Q.; Zhang, T.; Wang, S.; Liu, D. Characterization of Two Novel Mycoviruses from *Penicillium Digitatum* and the Related Fungicide Resistance Analysis. *Sci. Rep.* **2018**, *8*(1), 1–12. DOI: 10.1038/s41598-018-23807-3.
[32] Pitt, J. I.; Hocking, A. D. *Fungi and Food Spoilage II*; Chapman and Hall: London, 1997.
[33] Lugauskas, A.; Repeckiene, J.; Novosinskas, H. Micromycetes, Producers of Toxins, Detected on Stored Vegetables. *Ann. Agri. Environ. Med.* **2005**, *12*, 253–260.
[34] Batta, Y. A. Control of Postharvest Diseases of Fruit with an Invert Emulsion Formulation of *Trichoderma Harzianum* Rifai. *Postharvest Biol. Tec.* **2007**, *43*(1), 143–150. DOI: 10.1016/j.postharvbio.2006.07.010.
[35] Batta, Y. A. Quantitative Postharvest Contamination and Transmission of *Penicillium Expansum* (Link) Conidia to Nectarine and Pear Fruit by *Drosophila Melanogaster* (Meig.) Adults. *Postharvest Biol. Tec.* **2006**, *40*, 190–196. DOI: 10.1016/j.postharvbio.2006.01.006.
[36] Wang, Q.; Lai, T.; Qin, G.; Tian, S. Response of Jujube Fruits to Exogenous Oxalic Acid Treatment Based on Proteomic Analysis. *Plant Cell Physiol.* **2009**, *50*, 230–242. DOI: 10.1093/pcp/pcn191.
[37] Vilanova, L.; Teixidó, N.; Torres, R.; Usall, J.; Viñas, I. The Infection Capacity of *Penicillium Expansum* and *Penicillium Digitatum* on Apples and Histochemical Analysis of Host Response. *Int. J. Food Microbiol.* **2012**, *157*, 360–367. DOI: 10.1016/j.ijfoodmicro.2012.06.005.
[38] Spotts, R. A.; Sanderson, P. G.; Lennox, C. L.; Sugar, D.; Cervantes, L. A. Wounding, Wound Healing and Staining of Mature Pear Fruit. *Postharvest Biol. Tec.* **1998**, *13*, 27–36. DOI: 10.1016/S0925-5214(97)00079-3.
[39] Louw, J. P.; Pathogenic, K. L. *Penicillium* Spp. On Apple and Pear. *Plant Dis.* **2014**, *98*, 590–598. DOI: 10.1094/PDIS-07-13-0710-RE.
[40] Bardas, G. A.; Tzelepis, G. D.; Lotos, L.; Karaoglanidis, G. S. First Report of *Penicillium Glabrum* Causing Fruit Rot of Pomegranate (*Punica Granatum*) in Greece. *Plant Dis.* **2009**, *93*, 1347. DOI: 10.1094/PDIS-93-12-1347A.

[41] Elhariry, H.; Bahobial, A. A.; Gherbawy, Y. Genotypic Identification of *Penicillium Expansum* and the Role of Processing on Patulin Presence in Juice. *Food Chem. Toxicol.* **2011**, *49*, 941–946. DOI: 10.1016/j.fct.2010.12.018.
[42] Fugate, K. K.; Ferrareze, J. P.; Bolton, M. D.; Deckard, E. L.; Campbell, L. G. Postharvest Jasmonic Acid Treatment of Sugarbeet Roots Reduces Rot Due to *Botrytis Cinerea, Penicillium Claviforme*, and *Phoma Betae*. *Postharvest Biol. Tec.* **2012**, *65*, 1–4. DOI: 10.1016/j.postharvbio.2011.10.005.
[43] Palou, L.; Guardado, A.; Montesinos-Herrero, C. First Report of *Penicillium* Spp. And *Pidiella Granati* Causing Postharvest Fruit Rot of Pomegranate in Spain. *N. Dis. Rep.* **2010**, *22*, 21. DOI: 10.5197/j.2044-0588.2010.022.021.
[44] Spadaro, D.; Amatulli, M. T.; Garibaldi, A.; Gullino, M. L. First Report of *Penicillium Glabrum* Causing a Postharvest Fruit Rots of Pomegranate (*Punica Granatum*) in the Piedmont Region of Italy. *Plant Dis.* **2010**, *94*, 1066. DOI: 10.1094/PDIS-94-8-1066B.
[45] Farr, D. F.; Rossman, A. Y. ARS, USDA. Fungal Databases, Systematic Botany & Mycology Laboratory, **2016**. http://nt.ars-grin.gov/fungaldatabases/.
[46] Labuda, R.; Hudec, K.; Piecková, E.; Mezey, J.; Bohovič, R.; Mátéová, S.; Lukáč, S. S. *Penicillium Implicatum* Causes a Destructive Rot of Pomegranate Fruits. *Mycopathol.* **2004**, *157*(2), 217–223. DOI: 10.1023/B:MYCO.0000020599.95040.c6.
[47] Quaglia, M.; Moretti, C.; Cerri, M.; Linoci, G.; Cappelletti, S. U.; Taticchi, A. Effect of Extracts of Wastewater from Olive Milling in Postharvest Treatments of Pomegranate Fruit Decay Caused by *Penicillium Adametzioides*. *Postharvest Biol. Technol.* **2016**, *118*, 26–34. DOI: 10.1016/j.postharvbio.2016.03.012.
[48] Coates, L.; Johnson, G. Postharvest Diseases of Fruit and Vegetables. In *Plant Pathogens and Plant Diseases*, J.F. Brown and H.J. Ogle (Eds.), University of New England Printery, Australia, 1997; pp 533–548.
[49] Chatterton, S.; Wylie, A. C.; Punja, Z. K. Fruit Infection and Postharvest Decay of Greenhouse Tomatoes Caused by Penicillium Species in British Columbia. *Can. J. Plant Pathol.* **2012**, *34*(4), 524–535. DOI: 10.1080/07060661.2012.710069.
[50] Kim, W. K.; Sang, H. K.; Woo, S. K.; Park, M. S.; Paul, N. C.; Yu, S. H. Six Species of Penicillium Associated with Blue Mold of Grape. *Mycobiology*. **2007**, *35*(4), 180–185. DOI: 10.4489/MYCO.2007.35.4.180.
[51] Lichter, A.; Dvir, O.; Ackerman, M.; Feygenberg, O.; Pesis, E. Acidified Peel of Litchi Fruits Selects for Post-harvest Penicillium Decay. *Phytoparasitica*. **2004**, *32*, 226–236. DOI: 10.1007/BF02979817.
[52] Kim, W. K.; Hwang, Y. S.; Yu, S. H. Two Species of Penicillium Associated with Blue Mold of Yam in Korea. *Mycobiology*. **2008**, *36*(4), 217–221. DOI: 10.4489/MYCO.2008.36.4.217.
[53] Pitt, J. I.; Hocking, A. D. *Fungi and Food Spoilage*, 3rd ed.; Springer: Dordrecht, The Netherlands, 2009.
[54] Kumar, D.; Tannous, J.; Sionov, E.; Keller, N.; Prusky, D. Apple Intrinsic Factors Modulating the Global Regulator, LaeA, the Patulin Gene Cluster and Patulin Accumulation during Fruit Colonization by *Penicillium Expansum*. *Front. Plant Sci.* **2018**, *9*, 1–13. DOI: 10.3389/fpls.2018.01094.
[55] Andersen, B.; Smedsgaard, J.; Frisvad, J. C. *Penicillium Expansum*: Consistent Production of Patulin, Chaetoglobosins, and Other Secondary Metabolites in Culture and Their Natural Occurrence in Fruit Products. *J. Agric. Food Chem.* **2004**, *52*, 2421–2428. DOI: 10.1021/jf035406k.
[56] Barkai-Golan, R. Penicillium Mycotoxins. In *Mycotoxins in Fruits and Vegetables*; Barkai-Golan, R., Paster, N., Eds.; Elsevier: San Diego, CA, 2008b; pp 153–183.
[57] Saladino, F.; Manyes, L.; Luciano, F. B.; Manes, J.; Fernandez-Franzon, M.; Meca, G. Bioactive Compounds from Mustard Flours for the Control of Patulin Production in Wheat Tortillas. *LWT Food Sci. Technol.* **2016**, *66*, 101–107. DOI: 10.1016/j.lwt.2015.10.011.
[58] White, S.; O'Callagham, J.; Dobson, A. D. W. Cloning and Molecular Characterization of *Penicillium Expansum* Genes Upregulated under Conditions Permissive for Patulin Biosynthesis. *FEMS Microbiol. Lett.* **2006**, *255*, 17–26. DOI: 10.1111/j.1574-6968.2005.00051.x.

[59] Li, B.; Zong, Y.; Du, Z.; Chen, Y.; Zhang, Z.; Qin, G.; Zhao, W.; Tian, S. Genomic Characterization Reveals Insights into Patulin Biosynthesis and Pathogenicity in Penicillium Species. *Mol. Plant Microbe Interact.* **2015**, *28*(6), 635–647. DOI: 10.1094/MPMI-12-14-0398-FI.
[60] Snini, S. P.; Tannous, J.; Heuillard, P.; Bailly, S.; Lippi, Y.; Zehraoui, E.; Barreau, C.; Oswald, I. P.; Puel, O. Patulin Is a Cultivar-dependent Aggressiveness Factor Favouring the Colonization of Apples by *Penicillium Expansum*. *Mol. Plant Pathol.* **2016**, *17*(6), 920–930. DOI: 10.1111/mpp.12338.
[61] Tannous, J.; Keller, N. P.; Atoui, A.; El Khoury, A.; Lteif, R.; Oswald, I. P.; Puel, O. Secondary Metabolism in *Penicillium Expansum*: Emphasis on Recent Advances in Patulin Research. *Crit. Rev. Food Sci. Nutr.* **2018**, *58*(12), 2082–2098. DOI: 10.1080/10408398.2017.1305945.
[62] Kumar, D.; Barad, S.; Chen, Y.; Luo, X.; Tannous, J.; Dubey, A.; Glam Matana, N.; Tian, S.; Li, B.; Keller, N.; et al. LaeA Regulation of Secondary Metabolism Modulates Virulence in Penicillium Expansum and Is Mediated by Sucrose. *Mol. Plant Pathol.* **2017**, *18*(8), 1150–1163. DOI: 10.1111/mpp.12469.
[63] Sánchez-Torres, P.; Vilanova, L.; Ballester, A. R.; López-Pérez, M.; Teixidó, N.; Viñas, I.; Usall, J.; González-Candelas, L.; Torres, R. Unravelling the Contribution of the *Penicillium Expansum* PeSte12 Transcription Factor to Virulence during Apple Fruit Infection. *Food Microbiol.* **2018**, *69*, 123–135. DOI: 10.1016/j.fm.2017.08.005.
[64] Levin, E.; Ballester, A. R.; Raphael, G.; Feigenberg, O.; Liu, Y.; Norelli, J.; Gonzalez-Candelas, L.; Ma, J.; Dardick, C.; Wisniewski, M.; et al. Identification and Characterization of LysM Effectors in *Penicillium Expansum*. *PloS One*. **2017**, *12*(10), 0186023. DOI: 10.1371/journal.pone.0186023.
[65] Malandrakis, A. A.; Vattis, K. N.; Markoglou, A. N.; Karaoglanidis, G. S. Characterization of Boscalid-resistance Conferring Mutations in the SdhB Subunit of Respiratory Complex II and Impact on Fitness and Mycotoxin Production in *Penicillium Expansum* Laboratory Strains. *Pestic. Biochem. Physiol.* **2017**, *138*, 97–103. DOI: 10.1016/j.pestbp.2017.03.009.
[66] Fox, M. E.; Howlett, B. J. Secondary Metabolism: Regulation and Role in Fungal Biology. *Curr. Op. Microbiol.* **2008**, *11*, 481–487. DOI: 10.1016/j.mib.2008.10.007.
[67] Barad, S.; Sela, N.; Kumar, D.; Kumar-Dubey, A.; Glam-Matana, N.; Sherman, A.; Prusky, D. Fungal and Host Transcriptome Analysis of pH-regulated Genes during Colonization of Apple Fruits by *Penicillium Expansum*. *BMC Genom.* **2016**, *17*(1), 330. DOI: 10.1186/s12864-016-2665-7.
[68] Sanzani, S. M.; Reverberi, M.; Punelli, M.; Ippolito, A.; Fanelli, C. Study on the Role of Patulin on Pathogenicity and Virulence of *Penicillium Expansum*. *Int. J. Food Microbiol.* **2012**, *153*, 323–331. DOI: 10.1016/j.ijfoodmicro.2011.11.021.
[69] Baert, K.; Valero, A.; Meulenaer, B.; Samapundo, S.; Ahmed, M. M.; Bo, L.; Debevere, J.; Devlieghere, F. Influence of Storage Conditions of Apples on Growth and Patulin Production by *Penicillium Expansum*. *Int. J. Food Microbiol.* **2007**, *119*, 170–181. DOI: 10.1016/j.ijfoodmicro.2007.07.061.
[70] Schmidt-Heydt, M.; Magan, N.; Geisen, R. Stress Induction of Mycotoxin Biosynthesis Genes by Abiotic Factors. *FEMS Microbiol. Lett.* **2008**, *284*, 142–149. DOI: 10.1111/fml.2008.284.issue-2.
[71] Morales, H.; Sanchis, V.; Rovira, A.; Ramos, A. J.; Marín, S. Patulin Accumulation in Apples during Postharvest: Effect of Controlled Atmosphere Storage and Fungicide Treatments. *Food Control.* **2007**, *18*, 1443–1448. DOI: 10.1016/j.foodcont.2006.10.008.
[72] Zong, Y.; Li, B.; Tian, S. Effects of Carbon, Nitrogen and Ambient pH on Patulin Production and Related Gene Expression in *Penicillium Expansum*. *Int. J. Food Microbiol.* **2015**, *206*, 102–108. DOI: 10.1016/j.ijfoodmicro.2015.05.007.
[73] McCallum, J. L.; Tsao, R.; Zhou, T. Factors Affecting Patulin Production by *Penicillium Expansum*. *J. Food Protection.* **2002**, *65*, 1937–1942. DOI: 10.4315/0362-028X-65.12.1937.
[74] Barad, S.; Horowitz, S. B.; Kobiler, I.; Sherman, A.; Prusky, D. Accumulation of the Mycotoxin Patulin in the Presence of Gluconic Acid Contributes to Pathogenicity of *Penicillium Expansum*. *Mol. Plant Microbe Interact.* **2014**, *27*, 66–77. DOI: 10.1094/MPMI-05-13-0138-R.

[75] Sanzani, S. M.; Reverberi, M.; Geisen, R. Mycotoxins in Harvested Fruits and Vegetables: Insights in Producing Fungi, Biological Role, Conducive Conditions, and Tools to Manage Postharvest Contamination. *Postharvest Biol. Technol.* **2016**, *122*, 95–105. DOI: 10.1016/j.postharvbio.2016.07.003.
[76] Piemontese, L.; Solfrizzo, M.; Visconti, A. Occurrence of Patulin in Conventional and Organic Fruit Products in Italy and Subsequent Exposure Assessment. *Food Addit. Contam.* **2005**, *22*, 437–442. DOI: 10.1080/02652030500073550.
[77] Sarubbi, F.; Formisano, G.; Auriemma, G.; Arrichiello, A.; Palomba, R. Patulin in Homogenized Fruits and Tomato Products. *Food Control.* **2016**, *59*, 420–423. DOI: 10.1016/j.foodcont.2015.06.022.
[78] Wright, S. A. I. Patulin in Food. *Curr. Opin. Food Sci.* **2015**, *5*, 105–109. DOI: 10.1016/j.cofs.2015.10.003.
[79] Barkai-Golan, R.; Paster, N. Mouldy Fruits and Vegetables as a Source of Mycotoxins: Part 1. *World Mycotoxin J.* **2008**, *1*(2), 147–159. DOI: 10.3920/WMJ2008.x018.
[80] WHO. Evaluation of Certain Food Additives and Contaminants. Forty-fourth report of the joint FAO/WHO expert committee on food additives. *Geneva: Technol. Rep. Ser.* **1995**, *859*, 36–38.
[81] United States Food and Drug Administration (USFDA). *Compliance Policy Guide. Compliance Policy Guidance for FDA Staff. Sec. 510.150. Apple Juice, Apple Juice Concentrates, and Apple Juice Products-Adulteration with Patulin USFDA*, Rockville (USA), **2005**.
[82] Dukare, A. S.; Paul, S. Effect of Chitinolytic Biocontrol Bacterial Inoculation on the Soil Microbiological Activities and Fusarium Population in the Rhizosphere of Pigeonpea (*Cajanus Cajan*). *Ann. Plant Prot. Sci.* **2018**, *26*(1), 98–103. DOI: 10.5958/0974-0163.2018.00022.8.
[83] Dukare, A. S.; Prasanna, R.; Nain, L.; Saxena, A. K. Optimization and Evaluation of Microbe Fortified Composts as Biocontrol Agents against Phytopathogenic Fungi. *J. Microbiol. Biotech. Food Sci.* **2013**, *2*(5), 2272–2276.
[84] Nunes, C. A. Biological Control of Postharvest Diseases of Fruit. *Eur. J. Plant Pathol.* **2012**, *133*, 181–196. DOI: 10.1007/s10658-011-9919-7.
[85] Richard, W. J.; Prusky, D. Expression of an Antifungal Peptide in Saccharomyces, A New Approach for Biological Control of the Postharvest Disease Caused by Colletotrichum Coccodes. *Phytopathol.* **2002**, *92*, 33–37. DOI: 10.1094/PHYTO.2002.92.1.33.
[86] Comitini, F.; Mannazzu, I.; Ciani, M. Tetrapisispora Phaffii Killer Toxin Is a Highly Specific B-glucanase that Disrupts the Integrity of the Yeast Cell Wall. *Microb. Cell Fact.* **2009**, *8*, 55. DOI: 10.1186/1475-2859-8-55.
[87] Magliani, W.; Conti, S.; Travassos, L. R.; Polonelli, L. From Yeast Killer Toxins to Antibodies and Beyond. *FEMS Microbiol. Lett.* **2008**, *288*, 1–8. DOI: 10.1111/j.1574-6968.2008.01340.x.
[88] Zhang, Q.; Zhao, L.; Li, Z.; Li, C.; Li, B.; Gu, X.; Zhang, X.; Zhang, H. Screening and Identification of an Antagonistic Yeast Controlling Postharvest Blue Mold Decay of Pears and the Possible Mechanisms Involved. *Biol. Control.* **2019**, *133*, 26–33. DOI: 10.1016/j.biocontrol.2019.03.002.
[89] Wang, M.; Zhao, L.; Zhang, X.; Dhanasekaran, S.; Abdelhai, M. H.; Yang, Q.; Jiang, Z.; Zhang, H. Study on Biocontrol of Postharvest Decay of Table Grapes Caused by Penicillium Rubens and the Possible Resistance Mechanisms by *Yarrowia Lipolytica*. *Biol. Control.* **2019**, *130*, 110–117. DOI: 10.1016/j.biocontrol.2018.11.004.
[90] Di Francesco, A.; Mari, M.; Ugolini, L.; Baraldi, E. Effect of *Aureobasidium Pullulans* Strains against *Botrytis Cinerea* on Kiwifruit during Storage and on Fruit Nutritional Composition. *Food Microbiol.* **2018**, *72*, 67–72. DOI: 10.1016/j.fm.2017.11.010.
[91] Urbina, C. T.; Prieto, V. G.; Lopez, C. G.; Albores, F. V.; Reyes, D. B.; Muniz, C. A.; Barrios, D. O. Purification and Characterization of B-1, 3-glucanase from Candida Oleophila for the Biocontrol of *Penicillium Expansum*. *Res. Rev. J. Bot. Sci.* **2016**, *5*(1), 38–45.

[92] Guerrero, V.; Guigon, C.; Berlanga, D.; Ojeda, D. Complete Control of *Penicillium Expansum* on Apple Fruit Using a Combination of Antagonistic Yeast *Candida Oleophila*. *Chil. J. Agri. Res.* **2014**, *74*(4), 427–431. DOI: 10.4067/S0718-58392014000400008.

[93] Luo, Y.; Zeng, K.; Ming, J. Control of Blue and Green Mold Decay of Citrus Fruit by *Pichia Membranefaciens* and Induction of Defense Responses. *Sci. Hort.* **2012**, *135*, 120–127. DOI: 10.1016/j.scienta.2011.11.031.

[94] Platania, C.; Restuccia, C.; Muccilli, S.; Cirvilleri, G. Efficacy of Killer Yeasts in the Biological Control of *Penicillium Digitatum* on Tarocco Orange Fruits (*Citrus Sinensis*). *Food Microbiol.* **2012**, *30*, 219–225. DOI: 10.1016/j.fm.2011.12.010.

[95] Yanez-Mendizabal, V.; Usall, J.; Vinas, I.; Casals, C.; Marın, S.; Solsona, C.; Teixido, N. Potential of a New Strain of *Bacillus Subtilis* CPA- 8 to Control the Major Postharvest Diseases of Fruit. *Biocontrol Sci. Tec.* **2011**, *21*, 409–426. DOI: 10.1080/09583157.2010.541554.

[96] Lucon, C.; Guzzo, S.; de Jesus, C.; Pascholati, S.; de Goes, A. Postharvest Harpin or *Bacillus Thuringiensis* Treatments Suppress Citrus Black Spot in 'Valencia' Oranges. *Crop Prot.* **2010**, *29*, 766–772. DOI: 10.1016/j.cropro.2010.02.018.

[97] Mohammadi, P.; Tozlu, E.; Kotan, R.; Kotan Senol, M. Potential of Some Bacteria for Biological Control of Postharvest Citrus Green Mould Caused by *Penicillium Digitatum*.. *Plant Protect. Sci.* **2017**, *53*.1-10.

[98] Waewthongrak, W.; Pisuchpen, S.; Leelasuphakul, W. Effect of *Bacillus Subtilis* and Chitosan Applications on Green Mold (*Penicillium Digitatum* Sacc.) Decay in Citrus Fruit. *Postharvest Biol. Tec.* **2015**, *99*, 44–49. DOI: 10.1016/j.postharvbio.2014.07.016.

[99] Panebianco, S.; Vitale, A.; Polizzi, G.; Scala, F.; Cirvilleri, G. Enhanced Control of Postharvest Citrus Fruit Decay by Means of the Combined Use of Compatible Biocontrol Agents. *Biol. Control.* **2015**, *8*, 19–27. DOI: 10.1016/j.biocontrol.2015.02.001.

[100] Torres, R.; Nunes, C.; Garcia, J. M.; Abadias, M.; Vinas, I.; Manso, T.; Olmo, M.; Usall, J. Application of *Pantoea Agglomerans* CPA-2 in Combination with Heated Sodium Bicarbonate Solutions to Control the Major Postharvest Diseases Affecting Citrus Fruit at Several Mediterranean Locations. *Eur. J. Plant Pathol.* **2007**, *118*(1), 73–83. DOI: 10.1007/s10658-007-9120-1.

[101] Li, Q. L.; Ning, P.; Zheng, L.; JHuang, ., B.; Li, G. Q.; Hsiang, T. Fumigant Activity of Volatiles of *Streptomyces Globisporus* JK-1 against *Penicillium Italicum* on *Citrus Microcarpa*. *Postharvest Biol. Tec.* **2010**, *58*, 157–165. DOI: 10.1016/j.postharvbio.2010.06.003.

[102] Zhang, D.; Spadaro, D.; Valente, S.; Garibaldi, A.; Gullino, M. L. Cloning, Characterization, Expression and Antifungal Activity of an Alkaline Serine Protease of *Aureobasidium Pullulans* PL5 Involved in the Biological Control of Postharvest Pathogens. *Int. J. Food Microbiol.* **2012**, *153*, 453–464. DOI: 10.1016/j.ijfoodmicro.2011.12.016.

[103] Benhamou, N. Potential of Themycoparasite, *Verticillium Lecanii*, to Protect Citrus Fruit against *Penicillium Digitatum*, the Causal Agent of Green Mold, A Comparison with the Effect of Chitosan. *Phytopathol.* **2004**, *94*, 693–705. DOI: 10.1094/PHYTO.2004.94.7.693.

[104] Di Francesco, A.; Martini, C.; Mari, M. Biological Control of Postharvest Diseases by Microbial Antagonists, How Many Mechanisms of Action? *Eur. J. Plant Pathol.* **2016**, *145*, 711–717. DOI: 10.1007/s10658-016-0867-0.

[105] Spadaro, D.; Droby, S. Development of Biocontrol Products for Postharvest Diseases of Fruit, the Importance of Elucidating the Mechanisms of Action of Yeast Antagonists. *Trends Food Sci. Technol.* **2016**, *47*, 39–49. DOI: 10.1016/j.tifs.2015.11.003.

[106] Sharma, R. R.; Singh, D.; Singh, R. Biological Control of Postharvest Diseases of Fruits and Vegetables by Microbial Antagonists, A Review. *Biol. Control.* **2009**, *50*, 205–221. DOI: 10.1016/j.biocontrol.2009.05.001.

[107] Bencheqroun, S. M.; Bajji, M.; Massart, S.; Labhilili, M.; El-Jaafari, S.; Jijakli, M. H. *In Vitro* and *in Situ* Study of Postharvest Apple Blue Mold Biocontrol by *Aureobasidium Pullulans*, Evidence for the Involvement of Competition for Nutrients. *Postharvest Biol. Tec.* **2007**, *46*, 128–135. DOI: 10.1016/j.postharvbio.2007.05.005.

[108] Saraf, M.; Pandya, U.; Thakkar, A. Role of Allelochemicals in Plant Growth Promoting Rhizobacteria for Biocontrol of Phytopathogens. *Microbiol. Res.* **2014**, *169*, 18–29. DOI: 10.1016/j.micres.2013.08.009.
[109] Saravanakumar, D.; Ciavorella, A.; Spadaro, D.; Garibaldi, A.; Gullino, M. L. *Metschnikowia Pulcherrima* Strain MACH1 Out Competes *Botrytis Cinerea, Alternaria Alternata* and *Penicillium Expansum* in Apples through Iron Depletion. *Postharvest Biol. Tec.* **2008**, *49*, 121–128. DOI: 10.1016/j.postharvbio.2007.11.006.
[110] Calvo, J.; Calvente, V.; de Orellano, M. E.; Benuzzi, D.; de Tosetti, M. I. S. Biological Control of Postharvest Spoilage Caused by *Penicillium Expansum* and *Botrytis Cinerea* in Apple by Using the Bacterium *Rahnella Aquatilis. Int. J. Food Microbiol.* **2007**, *113*, 251–257. DOI: 10.1016/j.ijfoodmicro.2006.07.003.
[111] El-Tarabily, K. A. Rhizosphere-competent Isolates of Streptomycete and Non-streptomycete Actinomycetes Capable of Producing Cell-wall Degrading Enzymes to Control *Pythium Aphanidermatum* Damping-off Disease of Cucumber. *Can. J. Bot.* **2006**, *84*, 211–222. DOI: 10.1139/b05-153.
[112] Yu, T.; Wang, L.; Yin, Y.; Wang, Y.; Zheng, X. Effect of Chitin on the Antagonistic Activity of *Cryptococcus Laurentii* against *Penicillium Expansum* in Pear Fruit. *Int. J. Food Microbiol.* **2008**, *122*, 44–48. DOI: 10.1016/j.ijfoodmicro.2007.11.059.
[113] De Souza, J. T. A.; Arnould, C.; Deulvot, C.; Lemanceau, P.; Gianinazzi- Pearson, V.; Raaijmakers, J. M. Effect of 2, 4-diacetylphloroglucinol on Pythium, Cellular Responses and Variation in Sensitivity among Propagules and Species. *Phytopathol.* **2003**, *93*, 966–975. DOI: 10.1094/PHYTO.2003.93.8.966.
[114] Romanazzi, G.; Sanzani, S. M.; Bi, Y.; Tian, S.; Martınez, P. G.; Alkan, N. Induced Resistance to Control Postharvest Decay of Fruit and Vegetables. *Postharvest Biol. Technol.* **2016**, *122*, 82–94. DOI: 10.1016/j.postharvbio.2016.08.003.
[115] Lloyd, A. J.; William, A. J.; Winder, C. L.; Dunn, W. B.; Heald, J. K.; Cristescu, S. M.; Sivakumaran, A.; Harren, F. J.; Mulema, J.; Denby, K. Metabolomic Approaches Reveal that Cell Wall Modifications Play a Major Role in Ethylene Mediated Resistance against *Botrytis Cinerea. Plant J.* **2011**, *67*, 852–868. DOI: 10.1111/j.1365-313X.2011.04639.x.
[116] Yao, H. J.; Tian, S. P. Effects of a Biocontrol Agent and Methyl Jasmonate on Postharvest Diseases of Peach Fruit and the Possible Mechanisms Involved. *J. Appl. Microbiol.* **2005**, *98*, 941–950. DOI: 10.1111/jam.2005.98.issue-4.
[117] Jiang, F.; Zheng, X.; Chen, J. Microarray Analysis of Gene Expression Profile Induced by the Biocontrol Yeast *Cryptococcus Laurentii* in Cherry Tomato Fruit. *Gene.* **2009**, *430*, 12–16. DOI: 10.1016/j.gene.2008.09.036.
[118] Mari, M.; Bautista-Banos, S.; Selvakumar, D. Decay Control in the Postharvest System, Role of Microbial and Plant Volatile Organic Compounds. *Postharvest Biol. Technol.* **2016**, *122*, 70–81. DOI: 10.1016/j.postharvbio.2016.04.014.
[119] Arrebola, E.; Jacobs, R.; Korsten, L. Iturin A Is the Principal Inhibitor in the Biocontrol Activity of *Bacillus Amyloliquefaciens* PPCB004 against Postharvest Fungal Pathogens. *J. Appl. Microbiol.* **2010**, *108*, 386–395. DOI: 10.1111/jam.2009.108.issue-2.
[120] Di Francesco, A.; Ugolini, L.; Lazzeri, L.; Mari, M. Production of Volatile Organic Compounds by *Aureobasidium Pullulans* as a Potential Mechanism of Action against Postharvest Fruit Pathogens. *Biol. Control.* **2014**, *81*, 8–14. DOI: 10.1016/j.biocontrol.2014.10.004.
[121] Li, Q.; Ning, P.; Zheng, L.; Huang, J.; Li, G.; Hsiang, T. Effects of Volatile Substances of *Streptomyces Globisporus* JK-1 on Control of *Botrytis Cinerea* on Tomato Fruit. *Biol. Control.* **2012**, *61*, 113–120. DOI: 10.1016/j.biocontrol.2011.10.014.
[122] Chan, Z.; Qin, G.; Xu, X.; Li, B.; Tian, S. Proteome Approach to Characterize Proteins Induced by Antagonist Yeast and Salicylic Acid in Peach Fruit. *J. Proteome Res.* **2007**, *6*, 1677–1688. DOI: 10.1021/pr060483r.
[123] Mahunu, M.; Zhang, H. Y.; Yang, Q. Y.; Zhang, X. Y.; Li, D. D.; Zhou, Y. X. Improving the Biocontrol Efficacy of *Pichia Caribbica* with Phytic Acid against Postharvest Blue Mold and

Natural Decay in Apples. *Biol. Control.* **2016**, *92*, 172–180. DOI: 10.1016/j.biocontrol.2015.10.012.
[124] Cao, B.; Li, H.; Tian, S.; Qin, G. Boron Improves the Biocontrol Activity of *Cryptococcus Laurentii* against *Penicillium Expansum* in Jujube Fruit. *Postharvest Biol. Technol.* **2012**, *68*, 16–21. DOI: 10.1016/j.postharvbio.2012.01.008.
[125] Mekbib, S. B.; Regnier, T. J. C.; Korsten, L. Efficacy and Mode of Action of Yeast Antagonists for Control of *Penicillium Digitatum* in Oranges. *Trop. Plant Pathol.* **2011**, *36*(4), 233–240.
[126] Zheng, X. D.; Zhang, H. Y.; Sun, P. Biological Control of Postharvest Green Mold Decay of Oranges by *Rhodotorula Glutinis*. *Eur. Food Res. Technol.* **2005**, *220*, 353–357. DOI: 10.1007/s00217-004-1056-5.
[127] Ahima, J.; Zhang, X.; Yang, Q.; Zhao, L.; Tibiru, A. M.; Zhang, H. Biocontrol Activity of *Rhodotorula Mucilaginosa* Combined with Salicylic Acid against *Penicillium Digitatum* Infection in Oranges. *Biol. Control.* **2019**, *135*, 23–32. DOI: 10.1016/j.biocontrol.2019.04.019.
[128] Taqarort, N.; Echairi, A.; Chaussod, R.; Nouaim, R.; Boubaker, H.; Benaoumar, A. A.; Boudyach, E. Screening and Identification of Epiphytic Yeasts with Potential for Biological Control of Green Mold of Citrus Fruits. *World J. Microbiol. Biotechnol.* **2008**, *24*, 3031–3038. DOI: 10.1007/s11274-008-9849-5.
[129] Long, C. A.; Deng, B. X.; Deng, X. X. Commercial Testing of *Kloeckera Apiculata*, Isolate 34-9, for Biological Control of Postharvest Diseases of Citrus Fruit. *Ann. Microbiol.* **2007**, *57*, 203–207. DOI: 10.1007/BF03175208.
[130] Hershkovitz, V.; Ben-Dayan, C.; Raphael, G.; Pasmanik-Chor, M.; Liu, J.; Belausov, E.; Aly, R.; Wisniewski, M.; Droby, S. Global Changes in Gene Expression of Grapefruit Peel Tissue in Response to the Yeast Biocontrol Agent *Metschnikowia Fructicola*. *Mol. Plant Pathol.* **2012**, *13*, 338–349. DOI: 10.1111/j.1364-3703.2011.00750.x.
[131] Lu, L. F.; Lu, H. P.; Wu, C. Q.; Fang, W. W.; Yu, C.; Ye, C. Z. *Rhodosporidium Paludigenum* Induces Resistance and Defense-related Responses against *Penicillium Digitatum* in Citrus Fruit. *Postharvest Biol. Tec.* **2013**, *85*, 196–202. DOI: 10.1016/j.postharvbio.2013.06.014.
[132] Yan, Y.; Zhang, X.; Zheng, X.; Apaliya, M. T.; Yang, Q.; Zhao, L.; Gu, X.; Zhang, H. Control of Postharvest Blue Mold Decay in Pears by *Meyerozyma Guilliermondii* and Its Effects on the Protein Expression Profile of Pears. *Postharvest Biol. Technol.* **2018**, *136*, 124–131. DOI: 10.1016/j.postharvbio.2017.10.016.
[133] Castoria, R.; de Curtis, F.; Lima, G.; Caputo, L.; Pacifico, S.; de Cicco, V. *Aureobasidium Pullulans* (LS-30), an Antagonist of Postharvest Pathogens of Fruits, Study on Its Mode of Action. *Postharvest Biol. Tec.* **2001**, *32*, 717–724.
[134] Amin, S. S.; Ahmed, A. I.; Sidiq, S. A.; Mahm, H. A. Biological Control of Post-harvest Disease of Blue Mould (*Penicillium Expansum*) of Pear Fruit by Using Antagonist Microorganisms under Laboratory and Cold Storage Conditions. *Int. J. Curr. Res. Biosci. Plant Biol.* **2017**, *4*(1), 20–31. DOI: 10.20546/ijcrbp.
[135] Mercier, J.; Smilanick, J. L. Control of Green Mold and Sour Rot of Stored Lemon by Biofumigation with *Muscodor Albus*. *Biol. Control.* **2005**, *32*, 401–407. DOI: 10.1016/j.biocontrol.2004.12.002.
[136] Meziane, H.; Gavriel, S.; Ismailov, Z.; Chet, I.; Chernin, L.; Hofte, M. Control of Green and Blue Mould on Orange Fruit by *Serratia Plymuthica* Strains IC14 and IC1270 and Putative Modes of Action. *Postharvest Biol. Tec.* **2006**, *39*, 125–133. DOI: 10.1016/j.postharvbio.2005.10.007.
[137] Canamas, T. P.; Vinas, I.; Usall, J.; Torres, R.; Anguera, M.; Teixido, N. Control of Postharvest Diseases on Citrus Fruit by Preharvest Applications of Biocontrol Agent *Pantoea Agglomerans* CPA-2, Part II. Effectiveness of Different Cell Formulations. *Postharvest Biol. Tec.* **2008**, *49*(1), 96–106. DOI: 10.1016/j.postharvbio.2007.12.005.
[138] Yu, S.; Kim, Y.; Nam, H.; Lee, Y.; Lee, S.; Lee, K.; Lee, Y. H. Suppression of Green and Blue Mold in Postharvest Mandarin Fruit by Treatment of *Pantoea Agglomerans* 59-4. *Plant Pathol. J.* **2010**, *26*(4), 353–359. DOI: 10.5423/PPJ.2010.26.4.353.
[139] Chen, P. S.; Peng, Y. H.; Chung, W. C.; Chung, K. R.; Huang, H. C.; Huang J. W. Inhibition of *Penicillium Digitatum* and Citrus Green Mold by Volatile Compounds Produced by

Enterobacter Cloacae. *J. Plant Pathol. Microbiol.* **2016**, *7*, 339. DOI: 10.4172/2157-7471.1000339.
[140] Tripathi, P.; Dubey, N. Exploitation of Natural Products as an Alternative Strategy to Control Postharvest Fungal Rotting of Fruit and Vegetables. *Postharvest Biol. Tec.* **2003**, *32*, 235–245. DOI: 10.1016/j.postharvbio.2003.11.005.
[141] Tripathi, P.; Dubey, N.; Banerji, R.; Chansouria, J. Evaluation of Some Essential Oils as Botanical Fungitoxicants in Management of Post-harvest Rotting of Citrus Fruits. *World J. Microbiol. Biotechnol.* **2004**, *20*, 317–321. DOI: 10.1023/B:WIBI.0000023844.80464.59.
[142] Bakkali, F.; Averbeck, S.; Averbeck, D.; Idaomar, M. Biological Effects of Essential Oils-a Review. *Food Chem. Toxicol.* **2008**, *46*, 446–475. DOI: 10.1016/j.fct.2007.09.106.
[143] CFR. Code of Federal Regulations. *Title 21, Part 182.20. Food Additives Permitted for Direct Addition to Food for Human Consumption: Synthetic Flavoring Substances and Adjuvants*, U. S. Food and Drug Administration, USA, **2014**; pp. 56–63.
[144] Bajpai, V. K.; Baek, K. H.; Kang, S. C. Control of Salmonella in Foods by Using Essential Oils: A Review. *Food Res. Int.* **2012**, *45*, 722–734. DOI: 10.1016/j.foodres.2011.04.052.
[145] Carson, C. F.; Mee, B. J.; Riley, T. V. Mechanism of Action of Melaleuca Alternifolia (Tea Tree) Oil on Staphylococcus Aureus Determined by Time-kill, Lysis, Leakage, and Salt Tolerance Assays and Electron Microscopy. *Antimicrob. Agents Chemother.* **2002**, *46*, 1914–1920. DOI: 10.1128/AAC.46.6.1914-1920.2002.
[146] Ribes, S.; Fuentes, A.; Talens, P.; Barat, J. M. Prevention of Fungal Spoilage in Food Products Using Natural Compounds: A Review. *Crit. Rev. Food Sci. Nutr.* **2018**, 58(12), 2002-2016.
[147] Alilou, H.; Akssirar, M.; Hassani, L. M. I.; Chebli, B.; El Hakmoui, A.; Mellouki, F.; Rouhi, R.; Boira, H.; Blázquez, M. A. Chemical Composition and Antifungal Activity of *Bubonium Imbricatum* Volatile Oil. *Phytopathol. Mediterr.* **2008**, *47*(1), 3–10.
[148] Solaimani, B.; Ramezani, S.; Rahemi, M.; Saharkhiz, M. J. Biological Control of Postharvest Disease Caused by *Penicillium Digitatum* and *P. Italicum* on Stored Citrus Fruits by Shiraz Thyme Essential Oil. *Adv. Environ. Biol.* **2009**, *3*, 249–254.
[149] Badawy, F. M. I.; Sallam, M. A. N.; Ibrahim, A.; Asran, M. Efficacy of Some Essential Oils on Controlling Green Mold of Orange and Their Effects on Postharvest Quality Parameters. *Plant Pathol. J.* **2011**, *10*, 168–174. DOI: 10.3923/ppj.2011.168.174.
[150] Frankova, A.; Smid, J.; Bernardos, A.; Finkousova, A.; Marsik, P.; Novotny, D.; Legarová, V.; Pulkrabek, J.; Kloucek, P. The Antifungal Activity of Essential Oils in Combination with Warm Air Flow against Postharvest Phytopathogenic Fungi in Apples. *Food Control.* **2016**, *68*, 62–68. DOI: 10.1016/j.foodcont.2016.03.024.
[151] Soylu, E. M.; Soylu, S.; Kurt, S. Antimicrobial Activities of the Essential Oils of Various Plants against Tomato Late Blight Disease Agent *Phytophthora Infestans*. *Mycopathologia*. **2006**, *161*, 119–128. DOI: 10.1007/s11046-005-0206-z.
[152] Rao, A.; Zhang, Y. Q.; Muend, S.; Rao, R. Mechanism of Antifungal Activity of Terpenoid Phenols Resembles Calcium Stress and Inhibition of the TOR Pathway. *Antimicrob. Agents Chemother.* **2010**, *54*(2), 5062–5069. DOI: 10.1128/AAC.01050-10.
[153] Bennis, S.; Chami, F.; Chami, N.; Bouchikhi, T.; Remmal, A. Surface Alteration of *Saccharomyces Cerevisiae* Induced by Thymol and Eugenol. *Lett. Appl. Microbiol.* **2004**, *38*, 454–458. DOI: 10.1111/lam.2004.38.issue-6.
[154] Tao, N.; OuYang, Q.; Jia, L. Citral Inhibits Mycelial Growth of *Penicillium Italicum* by a Membrane Damage Mechanism. *Food Control.* **2014**, *41*, 116–121. DOI: 10.1016/j.foodcont.2014.01.010.
[155] Utama, I. M. S.; Wills, R. B. H.; Ben-yehoshua, S.; Kuek, C. *In Vitro* Efficacy of Plant Volatiles for Inhibiting the Growth of Fruit and Vegetable Decay Microorganisms. *J. Agri. Food Chem.* **2002**, *50*, 6371–6377. DOI: 10.1021/jf020484d.
[156] Palou, L.; Smilanick, J. L.; Droby, S. Alternatives to Conventional Fungicides for the Control of Citrus Postharvest Green and Blue Moulds. *Stewart Posthar. Rev.* **2008**, *4*, 1–16.
[157] da Cruz-cabral, L.; Fernández-Pinto, V.; Patriarca, A. Application of Plant Derived Compounds to Control Fungal Spoilage and Mycotoxin Production in Foods. *Int. J. Food Microbiol.* **2013**, *166*, 1–14.

[158] da Rocha Neto, A. C.; Maraschin, M.; Di Piero, R. M. Antifungal Activity of Salicylic Acid against *Penicillium Expansum* and Its Possible Mechanisms of Action. *Int. J. Food Microbiol.* **2015**, *215*, 64–70. DOI: 10.1016/j.ijfoodmicro.2015.08.018.

[159] Gatto, M. A.; Ippolito, A.; Linsalata, V.; Cascarano, N. A.; Nigro, F.; Vanadia, S.; Di Venere, D. Activity of Extracts from Wild Edible Herbs against Postharvest Fungal Diseases of Fruit and Vegetables. *Postharvest Biol. Tec.* **2011**, *61*(1), 72–82. DOI: 10.1016/j.postharvbio.2011.02.005.

[160] Sanzani, S. M.; De Girolamo, A.; Schena, L.; Solfrizzo, M.; Ippolito, A.; Visconti, A. Control of *Penicillium Expansum* and Patulin Accumulation on Apples by Quercetin and Umbelliferone. *Eur. Food Res. Technol.* **2009**, *228*, 381–389. DOI: 10.1007/s00217-008-0944-5.

[161] Klieber, A.; Scott, E.; Wuryatmo, E. Effect of Method of Application on Antifungal Efficacy of Citral against Postharvest Spoilage Fungi of Citrus in Culture. *Aust. Plant Pathol.* **2002**, *31*, 329–332. DOI: 10.1071/AP02034.

[162] Fisher, K.; Phillips, C. Potential Antimicrobial Uses of Essential Oils in Food: Is Citrus the Answer? *Trends Food Sci. Technol.* **2008**, *19*, 156–164.

[163] Wu, H.; Zhang, X.; Zhang, G. A.; Zeng, S. Y.; Lin, K. C. Antifungal Vapour-phase Activity of a Combination of Allyl Isothiocyanate and Ethyl Isothiocyanate against *Botrytis Cinerea* and *Penicillium Expansum* Infection on Apples. *J. Phytopathol.* **2011**, *159*, 450–455.

[164] Abd-El-Khair, H.; Hafez, O. Effect of Aqueous Extracts of Some Medicinal Plants in Controlling the Green Mould Diseases and Improvement of Stored "Washington" Navel Orange Quality. *Appl. Sci. Res.* **2006**, *2*, 664–674.

[165] Mekbib, S.; Regnier, T.; Korsten, L. Control of *Penicillium Digitatum* on Citrus Fruit Using Two Plant Extracts and Study of Their Mode of Action. *Phytoparasitica.* **2007**, *35*, 264–276. DOI: 10.1007/BF02981160.

[166] Askarne, L.; Talibi, I.; Boubaker, H.; Boudyach, E.; Msanda, F.; Saadi, B.; Serghini, M. A; Ben A. A. In Vitro and in Vivo Antifungal Activity of Several Moroccan Plants against *Penicillium Italicum*, the Causal Agent of Citrus Blue Mold. *Crop Prot.* **2012**, *40*, 53–58. DOI: 10.1016/j.cropro.2012.04.023.

[167] Marandi, R. J.; Hassani, A.; Ghosta, Y.; Abdollahi, A.; Pirzad, A.; Sefidkon, F. Control of *Penicillium Expansum* and *Botrytis Cinerea* on Pear with *Thymus Kotschyanus, Ocimum Basilicum* and *Rosmarinus Officinalis* Essential Oils. *J. Med. Plants Res.* **2011**, *5*(4), 626–634.

[168] Ikeura, H.; Somsak, N.; Kobayashi, F.; Kanlayanarat, S.; Hayata, Y. Application of Selected Plant Extracts to Inhibit Growth of *Penicillium Expansum* on Apple Fruits. *Plant Pathol. J.* **2011**, *10*(2), 79–84. DOI: 10.3923/ppj.2011.79.84.

[169] Lanciotti, R.; Gianotti, A.; Patrignani, F.; Belletti, N.; Guerzoni, M.; Gardini, F. Use of Natural Aroma Compounds to Improve Shelf-life and Safety of Minimally Processed Fruits. *Trends Food Sci. Technol.* **2004**, *15*, 201–208. DOI: 10.1016/j.tifs.2003.10.004.

[170] Talibi, I.; Boubaker, H.; Boudyach, E. H.; Ben Aoumar, A. A. Alternative Methods for the Control of Postharvest Citrus Diseases. *J. Appl. Microbiol.* **2014**, *117*, 1–17. DOI: 10.1111/jam.2014.117.issue-1.

[171] Du Plooy, W.; Regnier, T.; Combrinck, S. Essential Oil Amended Coatings as Alternatives to Synthetic Fungicides in Citrus Postharvest Management. *Postharvest Biol. Tec.* **2009**, *53*, 117–122. DOI: 10.1016/j.postharvbio.2009.04.005.

[172] Plaza, P.; Torres, P.; Usall, J.; Lamarca, N.; Vinas, I. Evaluation of the Potential of Commercial Postharvest Application of Essential Oils to Control Citrus Decay. *J. Hort. Sci. Biotechnol.* **2004**, *79*, 935–940. DOI: 10.1080/14620316.2004.11511869.

[173] Arras, G.; Usai, M. Fungitoxic Activity of 12 Essential Oils against Four Postharvest Citrus Pathogens: Chemical Analysis of *Thymus Capitatus* Oil and Its Effect in Sub Atmospheric Pressure Conditions. *J. Food Prot.* **2001**, *64*, 1025–1029. DOI: 10.4315/0362-028X-64.7.1025.

[174] Sattar, A.; Riaz, A.; Ahmed, S.; Hassan, I. Efficacy of Selected Plant Extracts for Inhibition of *Penicillium Expansum* Growth on Apple Fruits. *Pak. J. Phytopathol.* **2014**, *26*(1), 63–66.

[175] Singh, D.; Thakur, R. K.; Singh, D. Effect of Pre Harvest Sprays of Fungicides and Calcium Nitrate on Post-harvest Rot of Kinnow in Low Temperature Storage. *Plant Dis. Res.* **2003**, *18*, 9–11.

[176] Okigbo, R. N.; Putheti, R.; Achusi, C. T. Post-harvest Deterioration of Cassava and Its Control Using Extracts of *Azadirachta Indica* and *Aframomum Melegucta*. *E. J. Chem.* **2009**, *6*, 1274–1280. DOI: 10.1155/2009/680519.
[177] Jhalewar, J.; Sharma, R. R. Antifungal Efficacy of Botanicals against Major Postharvest Pathogens of Kinnow Mandarin and Their Use to Maintain Postharvest Quality. *Fruits*. **2014**, *69*, 223–237. DOI: 10.1051/fruits/2014012.
[178] Osman, A.; Abbas, E.; Mahgoub, S.; Siothy, M. Inhibition of *Penicillium Digitatum* in Vitro and in Postharvest Orange Fruit by a Soy Protein Fraction Containing Mainly β-conglycinin. *J. Gen. Plant Pathol.* **2016**, *82*, 293–301. DOI: 10.1007/s10327-016-0686-3.
[179] Yahyazadeh, M.; Omidbaigi, R.; Zare, R.; Taheri, H. Effect of Some Essential Oils on Mycelial Growth of *Penicillium Digitatum* Sacc. *World J. Microb. Biotechnol.* **2008**, *24*, 1445–1450. DOI: 10.1007/s11274-007-9636-8.
[180] Daferera, D. J.; Ziogas, B. N.; Polissiou, M. G. GC-MS Analysis of Essential Oils from Some Greek Aromatic Plants and Their Fungitoxicity on *Penicillium Digitatum*. *J. Agric. Food Chem.* **2000**, *48*, 2576–2581. DOI: 10.1021/jf990835x.
[181] Sargent, S. A.; Ritenour, M. A.; Brecht, J. K. *Handling, Cooling and Sanitation Techniques for Maintaining Postharvest Quality*; University of Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, University of Florida (US), EDIS, 2000.
[182] Gómez-López, V. M. *Decontamination of Fresh and Minimally Processed Fresh Produce*, 1st ed.; John Wiley and Sons, Inc, Ames, Iowa (US) 2012.
[183] Suslow, T. V. *Postharvest Chlorination. Basic Properties and Key Points for Effective Disinfection*; Publication 8003 by the Regents of the University of California, Division of Agriculture and Natural Resources, Davis, CA (US)1997.
[184] Smilanick, J. L.; Aiyabei, J.; Mlikota Gabler, F.; Doctor, J.; Sorenson, D.; Mackey, B. Quantification of the Toxicity of Aqueous Chlorine to Spores of *Penicillium Digitatum* and *Geotrichum Citriaurantii*. *Plant Dis.* **2002a**, *86*, 509–514. DOI: 10.1094/PDIS.2002.86.5.509.
[185] Sun, X.; Bai, J.; Ference, C.; Wang, Z.; Zhang, Y.; Narciso, J.; Zhou, K. Antimicrobial Activity of Controlled-release Chlorine Dioxide Gas on Fresh Blueberries. *J. Food Protect.* **2014**, *77*, 1127–1132. DOI: 10.4315/0362-028X.JFP-13-554.
[186] Trinetta, V.; Morgan, M. T.; Linton, R. H. Chlorine Dioxide for Microbial Decontamination of Food. In *Microbial Decontamination In the Food Industry: Novel Methods and Applications*; Demirci, A., Ngad, M.O. Eds., Elsevier Ltd, 2013a; pp. 533–562.
[187] Spotts, R. A.; Peters, B. B. Chlorine and Chlorine Dioxide for Control of d'Anjou Pear Decay. *Plant Dis.* **1980**, *64*, 1095–1097. DOI: 10.1094/PD-64-1095.
[188] Roberts, R. G.; Reymond, S. T. Chlorine Dioxide for Reduction of Postharvest Pathogen Inoculum during Handling of Tree Fruits. *Appl. Environ. Microbiol.* **1994**, *60*, 2864–2868. DOI: 10.1128/AEM.60.8.2864-2868.1994.
[189] Daus, A.; Kaplunov, T.; Zutahi, Y.; Lurie, S.; Lichter, A. Development of a System that Can Clean and Disinfect the Air and the Content of Storage Facilities and Its Potential for Decay Prevention of Table Grapes. The 6th International Conference on Postharvest Science, Antalya, Turkey, **2009**, pp. 73.
[190] Han, Y.; Selby, T. L.; Schultze, K. K.; Nelson, P. E.; Linton, R. H. Decontamination of Strawberries Using Batch and Continuous Chlorine Dioxide Gas Treatments. *J. Food Protect.* **2004**, *67*, 2450–2455. DOI: 10.4315/0362-028X-67.11.2450.
[191] Suslow, T. V. Ozone Applications for Postharvest Disinfection of Edible Horticultural Crops. *ANS Publ.* **2004**, *8133*, 1–8.
[192] Palou, L.; Smilanick, J. L.; Margosan, D. A. Ozone Applications for Sanitation and Control of Postharvest Diseases of Fresh Fruits and Vegetables. In *Recent Advances in Alternative Postharvest Technologies to Control Fungal Diseases in Fruits and Vegetables.* Transworld Research Network (India); Troncoso- Rojas, R., Tiznado-Hernández, M.E., González-León, A. Eds., 2006; pp. 1–32.
[193] Karaca, H.; Velioglu, Y. S. Ozone Applications in Fruit and Vegetable Processing. *Food Rev. Int.* **2007**, *23*, 91–106. DOI: 10.1080/87559120600998221.

[194] Yadav, L. *The Effect of Ozone on the Growth and Development of Selected Food Spoilage Fungi*; SBN-10:1-59942-352-9, ISBN-13: 978-1-59942-352-4. Dis-sertation.com, Boca Raton, Florida, U.S.A, 2009.
[195] Karaca, H.; Walse, S. S.; Smilanick, J. L. Effect of Continuous Gaseous Ozone Exposure on Fungicide Residues on Table Grape Berries. *Postharvest Biol. Tec.* **2012**, *64*, 154–159. DOI: 10.1016/j.postharvbio.2011.07.004.
[196] Antony-Babu, S.; Singleton, I. Effect of Ozone on Spore Germination, Spore Production and Biomass Production in Two Aspergillus Species. *Anton. Leeuw.* **2009**, *96*, 413–422. DOI: 10.1007/s10482-009-9355-2.
[197] Ames, Z. R.; Fjeld, K.; Feliziani, E.; Smilanick, J. L. Germination of Fungal Conidia after Exposure to Low Concentration Ozone Atmospheres. *Postharvest Biol. Tec.* **2013**, *83*, 22–26. DOI: 10.1016/j.postharvbio.2013.03.008.
[198] Metzger, C.; Barnes, J. D.; Singleton, I.; Andrew, P. Effect of Low-level Ozone Enrichment on the Quality and Condition of Citrus Fruit under Semi-commercial Conditions. Proceedings of IOA Conference and Exhibition, Valencia, Spain, **2007**; Vol. 11, pp. 1–7.
[199] Artes-Hernandez, F.; Aguayo, E.; Artes, F.; Toma's-Barberan, F. A. Enriched Ozone Atmosphere Enhances Bioactive Phenolics in Seedless Table Grapes after Prolonged Shelf Life. *J. Sci. Food Agric.* **2007**, *87*, 824–831. DOI: 10.1002/(ISSN)1097-0010.
[200] Ozkan, R.; Smilanick, J. L.; Karabulut, O. A. Toxicity of Ozone Gas to Conidia of *Penicillium Digitatum, Penicillium Italicum*, and *Botrytis Cinerea* and Control of Gray Mold on Table Grapes. *Postharvest Biol. Tec.* **2011**, *60*, 47–51. DOI: 10.1016/j.postharvbio.2010.12.004.
[201] Ali, Y.; Dolan, M. J.; Fendler, E. J.; Larson, E. L. Alcohols. In *Disinfection, Sterilization, and Preservation*; Block, S.S., Ed.; Lippincott, Williams, and Wilkins: New York, 2001; pp 229–253.
[202] Mlikota Gabler, F.; Mansour, M. F.; Smilanick, J. L.; Mackey, B. E. Survival of Spores of *Rhizopus Stolonifer, Aspergillus Niger, Botrytis Cinerea* and *Alternaria Alternata* after Exposure to Ethanol Solutions at Various Temperatures. *J. Appl. Microbiol.* **2004**, *96*, 1354–1360. DOI: 10.1111/jam.2004.96.issue-6.
[203] Smilanick, J. L.; Margosan, D. A.; Henson, D. J. Evaluation of Heated Solutions of Sulfur Dioxide, Ethanol, and Hydrogen Peroxide to Control Postharvest Green Mold of Lemons. *Plant Dis.* **1995**, *79*, 742–747. DOI: 10.1094/PD-79-0742.
[204] Chervin, C.; Westercamp, P.; Monteils, G. Ethanol Vapours Limit Botrytis Development over the Postharvest Life of Table Grapes. *Postharvest Biol. Tec.* **2005**, *36*, 319–322. DOI: 10.1016/j.postharvbio.2005.02.001.
[205] Imlay, J. A.; Linn, S. DNA Damage and Oxygen Radical Toxicity. *Sci.* **1988**, *240*, 1302–1309. DOI: 10.1126/science.3287616.
[206] Li, D.; Limwachiranon, J.; Li, L.; Zhang, L.; Xu, Y.; Fu, M.; Luo, Z. Hydrogen Peroxide Accelerated the Lignification Process of Bamboo Shoots by Activating the Phenylpropanoid Pathway and Programmed Cell Death in Postharvest Storage. *Postharvest Biol. Tec.* **2019**, *153*, 79–86. DOI: 10.1016/j.postharvbio.2019.03.012.
[207] Cerioni, L.; Rapisarda, V. A.; Hilal, M.; Prado, F. E.; Rodriguez-Montelongo, L. Synergistic Antifungal Activity of Sodium Hypochlorite, Hydrogen Peroxide, and Cupric Sulfate against *Penicillium Digitatum*. *J. Food Protect.* **2009**, *8*, 1660–1665. DOI: 10.4315/0362-028X-72.8.1660.
[208] Cerioni, L.; Volentini, S. I.; Prado, F. E.; Rapisarda, V. A.; Rodríguez-Montelongo, L. Cellular Damage Induced by a Sequential Oxidative Treatment on *Penicillium Digitatum*. *J. Appl. Microbiol.* **2010**, *109*, 1441–1449. DOI: 10.1111/jam.2010.109.issue-4.
[209] Kanetis, L.; Förster, H.; Adaskaveg, J. E. Optimizing Efficacy of New Postharvest Fungicides and Evaluation of Sanitizing Agents for Managing Citrus Green Mold. *Plant Dis.* **2008**, *92*, 261–269. DOI: 10.1094/PDIS-92-2-0261.
[210] Cerioni, L.; Sepulveda, M.; Rubio-Ames, Z.; Volentini, S. I.; Rodríguez-Montelongo, L.; Smilanick, J. L.; Ramallo, J.; Rapisarda, V. A. Control of Lemon Postharvest Diseases by Low-toxicity Salts Combined with Hydrogen Peroxide and Heat. *Postharvest Biol. Tec.* **2013**, *83*, 17–21. DOI: 10.1016/j.postharvbio.2013.03.002.

[211] Kumar, D. Salicylic Acid Signalling in Disease Resistance. *Plant Sci.* **2014**, *228*, 127–134. DOI: 10.1016/j.plantsci.2014.04.014.

[212] Saavedra, G. M.; Figueroa, N. E.; Poblete, L. A.; Cherian, S.; Figueroa, C. R. Effects of Preharvest Applications of Methyl Jasmonate and Chitosan on Postharvest Decay, Quality and Chemical Attributes of *Fragaria Chiloensis* Fruit. *Food Chem.* **2016**, *190*, 448–453. DOI: 10.1016/j.foodchem.2015.05.107.

[213] Sholberg, P. L.; Haag, P.; Hocking, R.; Bedfort, K. The Use of Vinegar Vapours to Reduce Postharvest Decay of Harvested Fruit. *Hort. Sci.* **2000**, *35*, 898–903. DOI: 10.21273/HORTSCI.35.5.898.

[214] Radi, M.; Jouybari, H. A.; Mesbahi, G.; Farahnaky, A.; Amiri, S. Effect of Hot Acetic Acid Solutions on Postharvest Decay Caused by *Penicillium Expansum* on Red Delicious Apples. *Sci. Horti.* **2010**, *126*, 421–425. DOI: 10.1016/j.scienta.2010.06.023.

[215] Venditti, T.; Dore, A.; Molinu, M. G.; Agabbio, M.; D'hallewin, G. Combined Effect of Curing Followed by Acetic Acid Vapour Treatments Improves Postharvest Control of *Penicillium Digitatum* on Mandarins. *Postharvest Biol. Tec.* **2009**, *54*, 111–114. DOI: 10.1016/j.postharvbio.2009.06.002.

[216] Zhu, Y.; Yu, J.; Brecht, J. K.; Jiang, T.; Zheng, X. Pre-harvest Application of Oxalic Acid Increases Quality and Resistance to *Penicillium Expansum* in Kiwifruit during Postharvest Storage. *Food Chem.* **2016**, *190*, 537–543. DOI: 10.1016/j.foodchem.2015.06.001.

[217] Wang, J. Y.; Li, H. Y. *Agrobacterium Tumefaciens*-mediated Genetic Transformation of the Phytopathogenic Fungus *Penicillium Digitatum*. *J. Zhejiang Univ. Sci. B.* **2008**, *9*, 823–828. DOI: 10.1631/jzus.B0860006.

[218] Sadeghi, M.; Zolfaghari, B.; Senatore, M.; Lanzotti, V. Antifungal Cinnamic Derivatives from Persian Leek (*Allium Ampeloprasum* Subsp. Persicum). *Phytochem. Lett.* **2013**, *6*, 360–363. DOI: 10.1016/j.phytol.2013.04.007.

[219] Zhang, Z.; Qin, G.; Li, B.; Tian, S. Effect of Cinnamic Acid for Controlling Gray Mold on Table Grape and Its Possible Mechanisms of Action. *Curr. Microbiol.* **2015**, *71*, 396–402. DOI: 10.1007/s00284-015-0863-1.

[220] El-Mougy, N. S.; El-Gamal, N. G.; Abd-El-Karrem, F. Use of Organic Acids and Salts to Control Postharvest Diseases of Lemon Fruits in Egypt. *Arch. Phytopathol. Plant Protect.* **2008**, *41*, 467–476. DOI: 10.1080/03235400600813532.

[221] Rahman, S. M. E.; Khan, I.; Oh, D. H. Electrolyzed Water as a Novel Sanitizer in the Food Industry: Current Trends and Future Perspectives. *Compr. Rev. Food. Sci.* **2016**, *15*, 471–490. DOI: 10.1111/1541-4337.12200.

[222] Gómez-López, V. M.; Gobet, J.; Selma, M. V.; Gil, M. I.; Allende, A. Operating Conditions for the Electrolytic Disinfection of Process Wash Water from the Fresh-cut Industry Contaminated with E. Coli O157: H7. *Food Control.* **2013**, *29*, 42–48. DOI: 10.1016/j.foodcont.2012.05.052.

[223] Fallanaj, F.; Sanzani, S. M.; Zavanella, C.; Ippolito, A. Salt Addition Improves the Control of Citrus Postharvest Diseases Using Electrolysis with Conductive Diamond Electrodes. *J. Plant Pathol.* **2013**, *95*, 373–383.

[224] Pinto, L.; Ippolito, A.; Baruzzi, F. Control of Spoiler Pseudomonas Spp. On Fresh Cut Vegetables by Neutral Electrolyzed Water. *Food Microbiol.* **2015**, *50*, 102–108. DOI: 10.1016/j.fm.2015.04.003.

[225] Anglada, A.; Urtiaga, A.; Ortiz, I. Contributions of Electrochemical Oxidation to Waste-water Treatment: Fundamentals and Review of Applications. *J. Chem. Technol. Biotechnol.* **2009**, *84*, 1747–1755. DOI: 10.1002/jctb.2214.

[226] Fallanaj, F.; Ippolito, A.; Ligorio, A.; Garganese, F.; Zavanella, C.; Sanzani, S. M. Electrolyzed Sodium Bicarbonate Inhibits *Penicillium Digitatum* and Induces Defence Responses against Green Mould in Citrus Fruit. *Postharvest Biol. Tec.* **2016**, *115*, 18–29. DOI: 10.1016/j.postharvbio.2015.12.009.

[227] Huang, Y. R.; Hung, Y. C.; Hsu, S. Y.; Huang, Y. W.; Hwang, D. F. Application of Electrolyzed Water in the Food Industry. *Food Control.* **2008**, *19*, 329–345. DOI: 10.1016/j.foodcont.2007.08.012.

[228] Montesinos-Herrero, C.; Palou, L. Synergism between Potassium Sorbate Dips and Brief Exposure to High CO2 or O2 at Curing Temperature for the Control of Citrus Postharvest Green and Blue Molds. *Crop Prot.* **2016**, *81*, 43–46. DOI: 10.1016/j.cropro.2015.12.005.
[229] Moscoso-Ramírez, P. A.; Montesinos-Herrero, C.; Palou, L. Control of Citrus Postharvest Penicillium Molds with Sodium Ethylparaben. *Crop Prot.* **2013**, *46*, 44–51. DOI: 10.1016/j.cropro.2012.12.007.
[230] Usall, J.; Smilanick, J.; Palou, L.; Denis-Arrue, N.; Teixidó, N.; Torres, R.; Viñas, I. Preventive and Curative Activity of Combined Treatments of Sodium Carbonates and *Pantoea Agglomerans* CPA-2 to Control Postharvest Green Mold of Citrus Fruit. *Postharvest Biol. Tec.* **2008**, *50*, 1–7. DOI: 10.1016/j.postharvbio.2008.03.001.
[231] Cerioni, L.; Lazarte, M. D. L. Á.; Villegas, J. M.; Rodríguez-Montelongo, L.; Volentini, S. I. Inhibition of *Penicillium Expansum* by an Oxidative Treatment. *Food Microbiol.* **2013a**, *33*, 298–301. DOI: 10.1016/j.fm.2012.09.011.
[232] Boonkorn, P.; Gemma, H.; Sugaya, S.; Setha, S.; Uthaibutra, J.; Whangchai, K. Impact of High-dose, Short Periods of Ozone Exposure on Green Mold and Antioxidant Enzyme Activity of Tangerine Fruit. *Postharvest Biol. Tec.* **2012**, *67*, 25–28. DOI: 10.1016/j.postharvbio.2011.12.012.
[233] Cerioni, L.; Sepulveda, M.; Rubio-Ames, Z.; Volentini, S. I.; Rodriguez-Montelongo, L.; Smilanick, J. L.; Ramallo, J.; Rapisarda, V. A. Control of Lemon Postharvest Diseases by Low-toxicity Salts Combined with Hydrogen Peroxide and Heat. *Postharvest Biol. Tec.* **2013b**, *83*, 17–21. DOI: 10.1016/j.postharvbio.2013.03.002.
[234] Qin, G.; Liu, J.; Cao, B.; Li, B.; Tian, S. Hydrogen Peroxide Acts on Sensitive Mitochondrial Proteins to Induce Death of a Fungal Pathogen Revealed by Proteomic Analysis. *PLoS One.* **2011**, *6*, 21945. DOI: 10.1371/journal.pone.0021945.
[235] Cerioni, L.; Rodríguez-Montelongo, L.; Ramallo, J.; Prado, F. E.; Rapisarda, V. A.; Volentini, S. I. Control of Lemon Green Mold by a Sequential Oxidative Treatment and Sodium Bicarbonate. *Postharvest Biol. Technol.* **2012**, *63*, 33–39. DOI: 10.1016/j.postharvbio.2011.08.006.
[236] Whangchai, K.; Saengnil, K.; Singkamanee, C.; Uthaibutra, J. Effect of Electrolyzed Oxidizing Water and Continuous Ozone Exposure on the Control of *Penicillium Digitatum* on Tangerine Cv 'Sai Nam Pung' during Storage. *Crop Prot.* **2010**, *29*, 386–389. DOI: 10.1016/j.cropro.2009.12.024.
[237] Aghdam, M. S.; Luo, Z.; Jannatizadeh, A.; Sheikh-Assadi, M.; Sharafi, Y.; Farmani, B.; Fard, J. R.; Razavi, F. Employing Exogenous Melatonin Applying Confers Chilling Tolerance in Tomato Fruits by Upregulating ZAT2/6/12 Giving Rise to Promoting Endogenous Polyamines, Proline, and Nitric Oxide Accumulation by Triggering Arginine Pathway Activity. *Food Chem.* **2019**, *275*, 549–556. DOI: 10.1016/j.foodchem.2018.09.157.
[238] Aghdam, M. S.; Jannatizadeh, A.; Luo, Z.; Paliyath, G. Ensuring Sufficient Intracellular ATP Supplying and Friendly Extracellular ATP Signaling Attenuates Stresses, Delays Senescence and Maintains Quality in Horticultural Crops during Postharvest Life. *Trends Food Sci. Technol.* **2018**, *76*, 67–81. DOI: 10.1016/j.tifs.2018.04.003.
[239] Deuchande, T.; Carvalho, S. M.; Larrigaudière, C.; Vasconcelos, M. W. Advances in Refrigerated and Controlled Atmosphere Storage of Fruits and Vegetables. In *Handbook of Research on Advances and Applications in Refrigeration Systems and Technologies*; Gaspar, P. D., da Silva, P.D., Eds.; IGI, Global: Hershey, 2015; pp 457.
[240] Lu, H.; Wang, K.; Wang, L.; Li, D.; Yan, J.; Ban, Z.; Luo, Z.; Li, L.; Yang, D. Effect of Superatmospheric Oxygen Exposure on Strawberry (Fragaria×ananassa Fuch.) Volatiles, Sensory and Chemical Attributes. *Postharvest Biol. Tec.* **2018**, *142*, 60–71. DOI: 10.1016/j.postharvbio.2018.04.007.
[241] Li, D.; Ye, Q.; Jiang, L.; Luo, Z. Effects of nano-TiO2 Packaging on Postharvest Quality and Antioxidant Activity of Strawberry (Fragaria × Ananassa Duch.) Stored at Low Temperature. *J. Sci. Food Agric.* **2017**, *97*, 1116–1123. DOI: 10.1002/jsfa.7837.

[242] Usall, J.; Ippolito, A.; Sisquella, M.; Neri, F. Physical Treatments to Control Postharvest Diseases of Fresh Fruits and Vegetables. *Postharvest Biol.Tec.* **2016**, *122*, 30–40. DOI: 10.1016/j.postharvbio.2016.05.002.

[243] Conway, W. S.; Janisiewicz, W. J.; Leverentz, B.; Saftner, R. A.; Camp, M. J. Control of Blue Mold of Apple by Combining Controlled Atmosphere, an Antagonist Mixture, and Sodium Bicarbonate. *Postharvest Biol. Tec.* **2007**, *45*, 326–333. DOI: 10.1016/j.postharvbio.2007.03.005.

[244] Li, D.; Li, L.; Xiao, G.; Limwachiranon, J.; Xu, Y.; Lu, H.; Yang, D.; Luo, Z. Effects of Elevated CO2 on Energy Metabolism and γ-aminobutyric Acid Shunt Pathway in Postharvest Strawberry Fruit. *Food Chem.* **2018**, *265*, 281–289. DOI: 10.1016/j.foodchem.2018.05.106.

[245] Li, D.; Zhang, X.; Li, L.; Aghdam, M. S.; Wei, X.; Liu, J.; Xu, Y.; Luo, Z. Elevated CO2 Delayed the Chlorophyll Degradation and Anthocyanin Accumulation in Postharvest Strawberry Fruit. *Food Chem.* **2019**, *285*, 163–170. DOI: 10.1016/j.foodchem.2019.01.150.

[246] Jin, P.; Zheng, G.; Huang, Y.; Wang, X.; Luo, Z.; Zheng, Y.-H. Hot Air Treatment Activates Defense Responses and Induces Resistance against *Botrytis Cinerea* in Strawberry Fruit. *J. Integr. Agric.* **2016**, *15*(11), 2658–2665. DOI: 10.1016/S2095-3119(16)61387-4.

[247] Luo, Z.; Xu, T.; Xie, J.; Zhang, L.; Xi, Y. Effect of Hot Air Treatment on Quality and Ripening of Chinese Bayberry Fruit. *J. Sci. Food Agric.* **2009**, *89*(3), 443–448. DOI: 10.1002/jsfa.v89:3.

[248] Karabulut, O. A.; Cohen, L.; Wiess, B.; Daus, A.; Lurie, S.; Droby, S. Control of Brown Rot and Blue Mold of Peach and Nectarine by Short Hot Water Brushing and Yeast Antagonists. *Postharvest Biol. Tec.* **2002**, *24*, 103–111. DOI: 10.1016/S0925-5214(01)00132-6.

[249] Porat, R.; Daus, A.; Weiss, B.; Cohen, L.; Fallik, E.; Droby, S. Reduction of Postharvest Decay in Organic Citrus Fruit by a Short Hot Water Brushing Treatment. *Postharvest Biol. Tec.* **2000**, *18*, 151–157. DOI: 10.1016/S0925-5214(99)00065-4.

[250] Spadoni, A.; Guidarelli, M.; Phillips, J.; Mari, M.; Wisniewski, M. Transcriptional Profiling of Apple Fruit in Response to Heat Treatment, Involvement of a Defense Response during *Penicillium Expansum*. *Postharvest Biol. Tec.* **2015**, *101*, 37–48. DOI: 10.1016/j.postharvbio.2014.10.009.

[251] Luria, N.; Sela, M.; Yaari, O.; Feygenberg, I.; Kobiler, A.; Prusky, D. De-novo Assembly of Mango Fruit Peel Transcriptome Reveals Mechanisms of Mango Response to Hot Water Treatment. *BMC Genom.* **2014**, *15*, 957. DOI: 10.1186/1471-2164-15-957.

[252] Zhang, H.; Wang, S.; Huang, X.; Dong, Y.; Zheng, X. Integrated Control of Postharvest Blue Mold Decay of Pears with Hot Water Treatment and *Rhodotorula Glutinis*. *Postharvest Biol. Tec.* **2008**, *49*, 308–313. DOI: 10.1016/j.postharvbio.2008.01.004.

[253] Strano, M. C.; Calandra, M.; Aloisi, V.; Rapisarda, P.; Strano, T.; Ruberto, G. Hot Water Dipping Treatment on Tarocco Orange Fruit and Their Effects on Peel Essential Oil. *Postharvest Biol. Technol.* **2014**, *94*, 26–34. DOI: 10.1016/j.postharvbio.2014.01.026.

[254] Smilanick, J. L.; Sorenson, D.; Mansour, M.; Aieyabei, J.; Plaza, P. Impact of a Brief Postharvest Hot Water Drench Treatment on Decay, Fruit Appearance, and Microbe Populations of California Lemons and Oranges. *Hort. Technol.* **2003**, *13*, 333–338. DOI: 10.21273/HORTTECH.13.2.0333.

[255] Luo, Z. Extending Shelf-life of Persimmon (*Diospyros Kaki* L.) Fruit by Hot Air Treatment. *Eur. Food Res. Technol.* **2006**, *222*, 149–154. DOI: 10.1007/s00217-005-0156-1.

[256] Pérez, A. G.; Luaces, P.; Olmo, M.; Sanz, C.; García, J. M. Effect of Intermittent 443 Curing on Mandarin Quality. *J. Food Sci.* **2005**, *70*, 64–68. DOI: 10.1111/j.1365-2621.2005.tb09048.x.

[257] Mai-Prochnow, A.; Murphy, A. B.; McLean, K. M.; Kong, M. G.; Ostrikov, K. K. Atmospheric Pressure Plasmas: Infection Control and Bacterial Responses. *Int. J. Antimicro. Agents.* **2014**, *43*, 508–517. DOI: 10.1016/j.ijantimicag.2014.01.025.

[258] Baier, M.; Foerster, J.; Schnabel, U.; Knorr, D.; Ehlbeck, J.; Herppich, W.; Schlüter, O. Direct Non-thermal Plasma Treatment for the Sanitation of Fresh Corn Salad Leaves: Evaluation of Physical and Physiological Effects and Antimicrobial Efficacy. *Postharvest Biol. Tec.* **2013**, *84*, 81–87. DOI: 10.1016/j.postharvbio.2013.03.022.

[259] Matan, N.; Puangjinda, K.; Phothisuwan, S.; Nisoa, M. Combined Antibacterial Activity of Green Tea Extract with Atmospheric Radio-frequency Plasma against Pathogens on Fresh-cut Dragon Fruit. *Food Control.* **2015**, *50*, 291–296.

[260] Niemira, B. A. Cold Plasma Reduction of *Salmonella* and *Escherichia Coli* O157: H7 on Almonds Using Ambient Pressure Gases. *J. Food Sci.* **2012**, *77*, 171–175. DOI: 10.1111/j.1750-3841.2011.02594.x.

[261] Nishioka, T.; Takai, Y.; Mishima, T.; Kawaradani, M.; Tanimoto, H.; Okada, K.; Misawa, T.; Kusakari, S. Low-pressure Plasma Application for the Inactivation of the Seed-borne Pathogen *Xanthomonas Campestris*. *Biocontrol Sci.* **2016**, *21*, 37–43. DOI: 10.4265/bio.21.37.

[262] Hertwig, C.; Reineke, K.; Ehlbeck, J.; Knorr, D.; Schlüter, O. Decontamination of Whole Black Pepper Using Different Cold Atmospheric Pressure Plasma Applications. *Food Control.* **2015**, *55*, 221–229. DOI: 10.1016/j.foodcont.2015.03.003.

[263] Ouf, S. A.; Mohamed, A. A. H.; El-Sayed, W. S. Fungal Decontamination of Fleshy Fruit Water Washes by Double Atmospheric Pressure Cold Plasma. *Clean*. **2016**, *44*, 134–142.

[264] Won, M. Y.; Lee, S. J.; Min, S. C. Mandarin Preservation by Microwave-powered Cold Plasma Treatment. *Innov. Food Sci. Emerg. Technol.* **2017**, *39*, 25–32. DOI: 10.1016/j.ifset.2016.10.021.

[265] Hayashi, N.; Yagyu, Y.; Yonesu, A.; Shiratani, M. Sterilization Characteristics of the Surfaces of Agricultural Products Using Active Oxygen Species Generated by Atmospheric Plasma and UV Light. *J. Appl. Phys.* **2014**, *53*, 05FR03. DOI: 10.7567/JJAP.53.05FR03.

[266] Dasan, B. G.; Boyaci, I. H.; Mutlu, M. Non-thermal Plasma Treatment of *Aspergillus* Spp. Spores on Hazelnuts in an Atmospheric Pressure Fluidized Bed Plasma System: Impact of Process Parameters and Surveillance of the Residual Viability of Spores. *J. Food Eng.* **2017**, *196*, 139–149. DOI: 10.1016/j.jfoodeng.2016.09.028.

[267] Dasan, B. G.; Mutlu, M.; Boyaci, I. H. Decontamination of *Aspergillus Flavus* and *Aspergillus Parasiticus* Spores on Hazelnuts via Atmospheric Pressure Fluidized Bed Plasma Reactor. *Int. J. Food Microbiol.* **2016**, *216*, 50–59. DOI: 10.1016/j.ijfoodmicro.2015.09.006.

[268] Ye, S. Y.; Song, X. L.; Liang, J. L.; Zheng, S. H.; Lin, Y. Disinfection of Airborne Spores of *Penicillium Expansum* in Cold Storage Using Continuous Direct Current Corona Discharge. *Biosyst. Eng.* **2012**, *113*, 112–119. DOI: 10.1016/j.biosystemseng.2012.06.013.

[269] Misra, N. N.; Jo, C. Applications of Cold Plasma Technology for Microbiological Safety in Meat Industry. *Trends Food Sci. Technol.* **2017**, *64*, 74–86. DOI: 10.1016/j.tifs.2017.04.005.

[270] Schluter, O.; Frohling, A. Cold Plasma for Bioefficient Food Processing. *Encycl. Food Microbiol.* **2014**, *2*, 948–953.

[271] Palgan, I.; Caminiti, I.; Muñoz, A.; Noci, F.; Whyte, P.; Morgan, D.; Cronin, D.; Lyng, J. Effectiveness of High Intensity Light Pulses (HILP) Treatments for the Control of *Escherichia Coli* and *Listeria Innocua* in Apple Juice, Orange Juice and Milk. *Food Microbiol.* **2011**, *28*, 14–20. DOI: 10.1016/j.fm.2010.07.023.

[272] Elmnasser, N.; Guillou, S.; Leroi, F.; Orange, N.; Bakhrouf, A.; Federighi, M. Pulsed-light System as A Novel Food Decontamination Technology: A Review. *Can. J. Microbiol.* **2007**, *53*, 813–821. DOI: 10.1139/W07-042.

[273] Ramos-Villarroel, A. Y.; Aron-Maftei, N.; Martin-Belloso, O.; Soliva-Fortuny, R. The Role of Pulsed Light Spectral Distribution in the Inactivation of *Escherichia Coli* and *Listeria Innocua* on Fresh-cut Mushrooms. *Food Control.* **2012**, *24*, 206–213. DOI: 10.1016/j.foodcont.2011.09.029.

[274] Xu, Y.; Charles, M. T.; Luo, Z.; Mimee, B.; Tong, Z.; Roussel, D.; Rolland, D.; Véronneau, P. Preharvest UV-C Treatment Affected Postharvest Senescence and Phytochemicals Alternation of Strawberry Fruit with the Possible Involvement of Abscisic Acid Regulation. *Food Chem.* **2019**, *299*, 125–138. DOI: 10.1016/j.foodchem.2019.125138.

[275] Huang, H.; Ge, Z.; Limwachiranon, J.; Li, L.; Li, W.; Luo, Z. UV-C Treatment Affects Browning and Starch Metabolism of Minimally Processed Lily Bulb. *Postharvest Biol. Tec.* **2017**, *128*, 105–111. DOI: 10.1016/j.postharvbio.2017.02.010.

[276] Lagunas-Solar, M. C.; Pin, C.; Macdonald, J. D.; Bolkan, L. Development of Pulsed UV Light Processes for Surface Fungal Disinfection of Fresh Fruits. *J. Food Prot.* **2006**, *69*(2), 376–384.

[277] Maftei, N. A.; Ramos-Villarroel, A. Y.; Nicolau, A. I.; Martin-Belloso, O.; Soliva-Fortuny, R. Influence of Processing Parameters on the Pulsed-light Inactivation of *Penicillium Expansum* in Apple Juice. *Food Control*. **2014**, *41*, 27–31. DOI: 10.1016/j.foodcont.2013.12.023.
[278] Ozer, N. P.; Demirci, A. Inactivation of *Escherichia Coli* O157: H7 and *Listeria Monocytogenes* Inoculated on Raw Salmon Fillets by Pulsed UV-light Treatment. *Int. J. Food Sci.Technol.* **2006**, *41*, 354–360. DOI: 10.1111/j.1365-2621.2005.01071.x.
[279] Paul, S.; Dukare, A. S.; Bandeppa, Manjunatha, B. S.; Annapurna, K. Plant Growth-Promoting Rhizobacteria for Abiotic Stress Alleviation in Crops. In *Advances in Soil Microbiology: Recent Trends and Future Prospects. Microorganisms for Sustainability*; Adhya, T., Mishra, B., Annapurna, K., Verma, D., Kumar, U., Eds.; Springer: Singapore, 2017; Vol. 4, pp 57–79.
[280] Sangwan, S.; Dukare, A. Microbe-Mediated Bioremediation: An Eco-friendly Sustainable Approach for Environmental Clean-Up. In *Advances in Soil Microbiology: Recent Trends and Future Prospects. Microorganisms for Sustainability*; Adhya, T., Lal, B., Mohapatra, B., Paul, D., Das, S., Eds.; Springer: Singapore, 2018; Vol. 3, pp 145–163.