

Review

# Natural Plant Extracts: An Update about Novel Spraying as an Alternative of Chemical Pesticides to Extend the Postharvest Shelf Life of Fruits and Vegetables

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**Abstract:** Fresh fruits and vegetables, being the source of important vitamins, minerals, and other plant chemicals, are of boundless importance these days. Although in agriculture, the green revolution was a milestone, it was accompanied by the intensive utilization of chemical pesticides. However, chemical pesticides have hazardous effects on human health and the environment. Therefore, increasingly stimulating toward more eco-friendly and safer alternatives to prevent postharvest losses and lead to improving the shelf life of fresh fruits and vegetables. Proposed alternatives, natural plant extracts, are very promising due to their high efficacy. The plant-based extract is from a natural source and has no or few health concerns. Many researchers have elaborated on the harmful effects of synthetic chemicals on human life. People are now much more aware of safety and health concerns than ever before. In the present review, we discussed the latest research on natural alternatives for chemical synthetic pesticides. Considering that the use of plant-based extracts from aloe vera, lemongrass, or neem is non-chemical by-products of the fruits and vegetable industry, they are proved safe for human health and may be integrated with economic strategies. Such natural plant extracts can be a good alternative to chemical pesticides and preservatives.

**Keywords:** human health; pesticide utilization; postharvest quality; shelf life

## 1. Introduction

Fresh fruits and vegetables keep the activities of natural biological processes even after harvest from parental plants. Such a process could bring about several undesirable changes that ultimately contribute to postharvest quality because of shriveling, mass loss, poor consumption quality, and short storage life [1,2]. These are the significant limiting restrictions defining the keenness of fresh fruits and vegetables in the marketplace [3]. The ripening is a continuous process of ripening in many fruits and vegetables even after harvest. It is a highly synchronized evolving progression that conveys by a series of biochemical changes such as color changes, reduction of astringency, volatile production, tissue softening, seed maturation, taste, and many others, leading to the quality deterioration [4]. Postharvest

diseases are the main factors that contribute to quality losses to the produce. Additionally, wrong transportation and preservation can influence fresh produces. After harvesting, the product can be more susceptible to numerous postharvest ailments and diseases instigated by bacterial and fungal pathogens [5]. Approximately 40% of fruit and vegetable losses were reported throughout the postharvest handling and supply chain [6].

For many years, farmers preserved fruits and vegetables using synthetic chemical preservatives. These chemicals, on the one hand, increase the shelf life and maintain the postharvest quality of fruits and vegetables. On the other hand, such chemicals bring potentially dangerous compounds into the food chain and cause harmful effects on consumers' health [7,8]. Continuously, postharvest disease management has been conducted by using chemicals, but improper use of such chemicals can ground numerous unwanted penalties [9]. The fast decline in the quality attributes of fresh fruits and vegetables during the postharvest period is a problematic issue in the present times.

Pesticide is a multifaceted word that is used collectively for all chemicals that are applied to terminate pests; this includes insecticides, fungicides, herbicides, etc. [10]. These are the chemicals that farmers use in agricultural land, gardens, and other areas to destroy pests and microorganisms, which are undesirable. In addition to being effective against harmful pests and microorganisms, these pesticides in higher concentrations also can cause harm to humans. A report by the World Health Organization (WHO) explored that about 1 million humans are directly being affected by acute poisoning caused by the abused use of pesticides (death rate of 0.4–1.9% every year) [11]. Exported fruits are exposed to a prolonged handling and supply chain, so often follow-on loss in terms of quality such as decay, shrivel, over-ripeness, and weight loss. The industry of fruits and vegetables strongly relies on the application of synthetic chemicals such as chlorine dioxide, nitric oxide, salicylic acid, and 1-methyl cyclopropane as a postharvest treatment for maximizing the economic potential of their products [12,13]. Though such chemical treatments show potential effects in maintaining the quality and prolonging the shelf life of fruits and vegetables, there are still many disadvantages to their application [14]. The use of chemical agents on fruits seems to bias objectionable when it comes to consumer preference. Nowadays, consumers are seeking safer and healthier foods with the lowest additives or synthetic agent addition [15]. Chlorpyrifos is one of the pesticides for fruits and vegetables that are showing up. That is nerve poisoning organophosphorus insecticide, which is used for conventionally produced citrus fruits. Chlorpyrifos is a hazardous material for humans and the environment.

Pesticide poisoning is a major public health problem and accounts for nearly 300,000 deaths per year worldwide. The human body exposed to pesticides has more DNA damage even if there is no detectable quantity of pesticides in the body. Their metabolites present in human biological matrices not only affect the DNA but also inhibit the acetylcholinesterase (AChE) activity [16]. The oxidative stress due to pesticide exposure to the human body may lead to DNA damage, the development of Parkinson's and Alzheimer's, and many other disorders [17]. In contrast, there is a noteworthy sign that agricultural use of these pesticides has a foremost influence on the quality of water, and when used, they can cause severe health concerns [18]. Consumers are currently concerned about the use of fungicide-sprayed fruits, as their active compounds and co-formulants have been linked with a variety of health and environmental contamination concerns. Because the modes of action of the drug are not type-specific, concerns about the environmental risk associated with them are expressed in different ways (for example, residues in food and drinking water) over a short period (e.g., skin and eye pain, headache, dizziness, and lightheadedness) to common side effects (e.g., cancer, form, and diabetes). Their risks are difficult to explain due to exposure of different groups (e.g., duration and level of exposure, types of disinfectants, relative to toxicity and duration) and environmental characteristics of the group concerned. Therefore, the development of pesticides and other combined experimental methods (Integrated Pest Management) is required to minimize the effects of such chemical pesticides [19]. The

increasing demand for safe and healthy production needs to transfer from synthetic to natural safe chemicals. Plant extracts are of significant importance in this regard [10].

Plant extract use in the world market has a significant scope. This market is growing very fast, and the growth is projected to reach USD 55.3 billion by 2026 [20]. Consumable plant-based extracts can be used on fresh products to improve and maintain their quality and increase storage life and time usability. The high demand for food products free from pesticide residues has pushed researchers to work progressively in search of environment-friendly alternatives with fewer or no health hazards. Plant-based extracts are known to be safer natural preservatives and turn out to be a steadfast substitute for hazardous synthetic chemical pesticides and preservatives, particularly for the resist postharvest diseases and maintaining postharvest quality [21]. Thus, the utilization of affordable plant-based natural preservatives has shown great reflection for preserving fruit quality and shelf life with great effectiveness. Moreover, around the world, consumer awareness is increasing concerning the quality of fruits and vegetables and their safety of high nutrition. Consequently, there is an increasing interest in replacing synthetic chemicals with natural plant extracts, for instance, aloe vera, neem, lemongrass, and several types of oligosaccharides for preserving postharvest quality and enhancing the shelf life of fruits and vegetables. In this sense, utilizing natural plant-based extracts as preservatives has paid a significant attraction in postharvest treatments of fruits and vegetables for increasing the shelf life and maintaining the nourishing components [22].

The extracts from different plants accessible worldwide at a low cost can be used to cope with losses due to postharvest diseases. Such plant extracts impose no damaging effects on the quality of the produce and public health. Extracts of plants with positive potential for antioxidant activity have been widely studied for scavenging the free radicals and strong capacity caused by the biologically active components such as punicalagin, ellagic, gallic, and chlorogenic acids [23–25]. Researchers examined pomegranate peel extracts as a natural inhibitor of pathogenic fungi and bacteria [23–25]. Plant extract application has been extensively reported to minimize postharvest spoilage, prolong shelf life, and maintain the postharvest quality of fruits and vegetables. The potential application of natural products such as antimicrobials and antioxidants on fruits and vegetables may be considered as alternatives for the conservation of postharvest quality and prolongation of their shelf life [26].

This review aims to provide a general view of the utilization of natural plant extracts as an alternative to chemical pesticides for fruits and vegetable spraying, specifically as edible spraying to protect the spoilage of fresh fruits and vegetables, the health of consumers, and the environment. An overview of the natural plant extract utilization is conducted, and the recent studies of their impact on microbiological safety, prolongation of shelf life, and nutritional and physiochemical quality of fruits and vegetables are presented.

## 2. Properties of Natural Plant Extract

Plant extract utilization has been increased as an additive in the food industry due to the presence of bioactive compounds such as polyphenols and carotenoids [27]. These natural extracts have antimicrobial and antioxidant properties [28]. Polyphenols and carotenoids prevent oxidative changes, development of off flavor, and increase color stability and shelf life of the product. These natural extracts can be utilized to replace the synthetic compounds, which are harmful and exerts carcinogenic impacts. Moreover, there is also a big challenge of efficient extraction of natural extracts, their applications in industry, and producing products with fewer health hazards. Consumers prefer high-quality products that are without chemical additives and have a high shelf life. Different types of natural edible coatings have been developed to fulfill society's demands [29,30].

### 2.1. Aloe Vera Extract

Aloe vera is an herbal plant and has medicinal properties; hence, its applications in food, pharmaceutical and cosmetic industries have been studied [31]. It has a jelly-

like texture and is composed of various bioactive compounds as well as carbohydrates, proteins, fibers, soluble sugars, vitamins, minerals, amino acids, organic acids, and phenolic compounds [32]. In functional food development, aloe vera is utilized as an edible coating film [31]. Aloe vera gel is an excellent example of active packaging due to its antimicrobial and antioxidant properties. It has been investigated as an effective preservative in terms of shelf-life extension [33]. Aloe vera gel exhibits antifungal properties to prevent postharvest diseases. Aloe vera gel has proven effective in reducing the spore survival of *Penicillium*, *Botrytis* and *Alternaria* by 15–20% and those of *Rhizoctonia*, *Fusarium*, and *Colletotrichum* by 22–38%. Aloe vera gel utilization in blueberries [34], strawberries [35], and avocado [36] as antifungal coating has been proven excellent. Additionally, aloe vera has antibacterial activities against *Bacillus cereus*, *Salmonella typhimurium*, *Escherichia coli*, and *Klebsiella pneumoniae*. All aforementioned benefits evidenced its selection excellent as coating material. Aloe vera consists of active compounds in its profile such as vitamins, enzymes, minerals, sugars, lignin, saponins, salicylic acid, and amino acids.

### 2.2. Lemongrass Extract

Lemongrass consists of bioactive compounds which are beneficial for health. Lemongrass contains terpenoid compounds such as geranial, linalool, neral, pinene, myrcene, and terpinene. The terpene helps in the degradation of bacteria and causes toxic effects on cell membrane and cytoplasm. The antibacterial activity causes structural changes and cell lysis. Therefore, lemongrass assists in preservation and shelf-life extension. Lemongrass also contains allelochemicals which affect the insects thus also known as biopesticide. Lemongrass insecticidal properties are referred to as bioactive acyclic and cyclic terpenes. It can kill insects at the larval stage, such as cabbage looper [37], and distract insects due to the presence of caryophyllene (0.57%), germacrene D (2.24%), and caryophyllene oxide (0.58%). Lemongrass's effective utilization stops the growth of microbes [38]. Lemongrass is useful to minimize the diseases as an edible coating in fresh whole fruit and cut fruit such as Fuji apples [39], pomegranate arils [40], fresh-cut pineapple [41], and strawberry [42].

### 2.3. Neem Extract

Neem extract has antifungal and antibacterial properties, which come from the Meliaceae family. This plant has antioxidant, microbial, and therapeutic properties. Its extract contains several bioactive compounds such as azadirachtin (the best limonoid compound [43,44]), salannin, nimbidin, margolonone, gedunin, and others, which are applied as insect mite repellents. In an experiment, it was applied as an edible coating on tomatoes, where it plays a crucial role in improving texture, color, and flavor [45]. Neem extracts are famous in India for medicinal properties and are obtained from various parts of the plants and found to contain polyphenols (e.g., tannins, lignins, and flavanoids) possessing strong antioxidant [46,47], antibacterial [48,49], as well as anti-inflammatory and immunomodulatory properties [50,51]. A study showed antibacterial properties of neem extract against *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, and *Salmonella typhi*, and a 90% inhibition rate received [52]. Phenolic compounds in neem extract profile exhibit high antioxidant properties than synthetic antioxidants [45,46]. There is a major shift towards natural extracts from synthetic chemicals due to their harmful effects on human health and the environment [53].

## 3. Use of Synthetic Chemical Pesticides

There are many advantages of pesticides, including increasing crop yield, managing vector/diseases, and killing or inhibiting hazardous pests. Despite the beneficial effects of pesticides, the adverse effects of pesticides should not be unnoticed. Both the atmosphere and human beings are seriously in danger by pesticide usage. Pesticides also disturb nature, water, and soil and cause harmful effects, leading to a dangerous impact on livestock, birds, plants, and human beings [54]. Biodiversity is often disrupted by pesticides, and continuing direct or indirect exposure to pesticides can pose serious risks to human health. Acute

health conditions such as cancer, diabetes, reproductive disorders, respiratory disorders, and neurological disorders can be caused by them [55]. The abused use of harmful chemical pesticides in the agricultural environment makes it difficult to distinguish between the effects on the environment and the effects on the health of the consumers.

The lack of proper management of the fruits after harvest causes tremendous economic losses, growing poverty, hunger, and malnutrition. Globally, various postharvest technologies and synthetic chemical treatments have been used to minimize postharvest losses, but these are recorded to increase the risk to human health and the environment [56]. As an effective and cost-effective method for pest control, pesticides are deliberately considered. However, not only do they kill the target creature due to their mechanism of action, but they also damage non-target creatures, including humans. About 3 million annual cases of pesticide poisoning and up to 220,000 deaths are recorded by the World Health Organization, primarily in developing countries [57]. Additionally, particularly young and developing creatures are highly susceptible to their adverse effects due to the non-specific use of pesticides and unintentional awareness. The toxic effect of pesticide exposure was primarily determined by the quantity of pesticide as well as the persistence duration. Some pesticides are highly poisonous to humans, with just a few drops in the mouth or on the skin resulting in adverse result. Their persistent and long-term exposure to other less toxic pesticides may also cause adverse effects. In most developed countries, pesticide residues in fruits, vegetables, and food have been tracked for decades, while those in developing countries are not properly recorded [56].

### *3.1. Synthetic Chemical Pesticides: Effects on Human Health*

The research found an increase in the incidence of prostate, breast, bladder, lung, colon leukemia, and multiple myeloma cancers due to constant exposure to certain chemicals and pesticides [58]. A meta-analysis has shown that exposure to pesticides can cause genetic alteration in the genes involved in pathogenesis. Environmental exposures to pesticides have raised the likelihood of changes in genes, including the GST, PON-1, MDR-1, and SNCAA [59]. The implications of different studies have established the association between pesticide exposure and diabetes. The risk of diabetes has been exacerbated by constant interaction with pesticides. A strong association between organochlorine compounds and diabetes was found, and the incidence of type 2 diabetes was similarly associated with organophosphate [60]. Elevated concentrations of dichlorodiphenyltrichloroethane (DDT) and heptachlor epoxide pollutants in human blood have been related to diabetes and related nephropathy [61]. Increasing research has linked obesity to chronic pesticides such as DDT, its DDE metabolite, and other harmful chemicals such as nitrosamines, benzoates, sulfites, sorbates, parabens, formaldehyde, BHT, and BHA [62]. A specific instance population examination in Bang Rakam demonstrated an increased risk of diabetes caused by exposure to pesticides [63]. They found that three insecticides (endosulfan, mevinphos, and Sevin) and a fungicide (benlate) were the main cause of diabetes type 2 mellitus. The preparation of imazamox-based herbicides reduced bislet cell size and triggered an increase in blood sugar and calcium [64]. Exposure to pesticides may raise the risk of lung diseases, as well as the issue of morbidity and mortality [65]. Occupational exposure among agricultural producers was associated with a higher incidence of pulmonary symptoms, including lung dysfunction, and a progressive incidence of chronic respiratory diseases [66]. Pesticides, which have been closely linked to immune disorders, have been documented to increase the risk of cancer, respiratory problems, organ ailments, system defects, nervous system abnormalities, and asthma [67]. The link between the use of pesticides and thyroid cancer has been tested in many epidemiological studies. The prevalence of thyroid cancer is high relative to the normal community throughout the Agricultural Health Study (AHS) cohort [68].

### 3.2. Synthetic Chemical Pesticides: Effects on the Environment

Pesticides as well as other chemical products have been an integral part of modern agricultural production systems. Over the past century, these chemicals have contributed to a dramatic increase in crop yields through insect and disease management [69]. The rapid expansion in the world population also emphasizes the need to maximize the supply of food. Furthermore, the widespread use of these pesticides has many negative impacts, ranging from environmental pollution to ecosystem destruction [70,71]. Environmental and agricultural land diffusion of agrochemical pollutants causes catastrophic ecosystem pollution (i.e., dust, air, soil, sediments, and water) and spoilage of human food across the globe [72]. Soil, water, grass as well as some other flora may be contaminated by pesticides. In addition to killing insects or weeds, other animals such as birds, fish, beneficial insects, and non-target plants might be contaminated by pesticides. In general, insecticides are by far the most hazardous type of pesticide, but herbicides may also pose risks to non-target species [73].

A large number of pesticides and other chemicals have been released into the environment due to agricultural and commercial growth [74]. In current agricultural practices, the widespread use of chemical fertilizers has resulted in the pollution of various environmental matrices, including air, soil, and water. Resultantly, human health and non-targeted organisms are adversely affected by polluted environmental geometries in many ways. Mostly through soil leaching, surface run-off, underground run-off, and accidental leakage, traces of these toxic compounds may enter rivers, surface water, and groundwater [75].

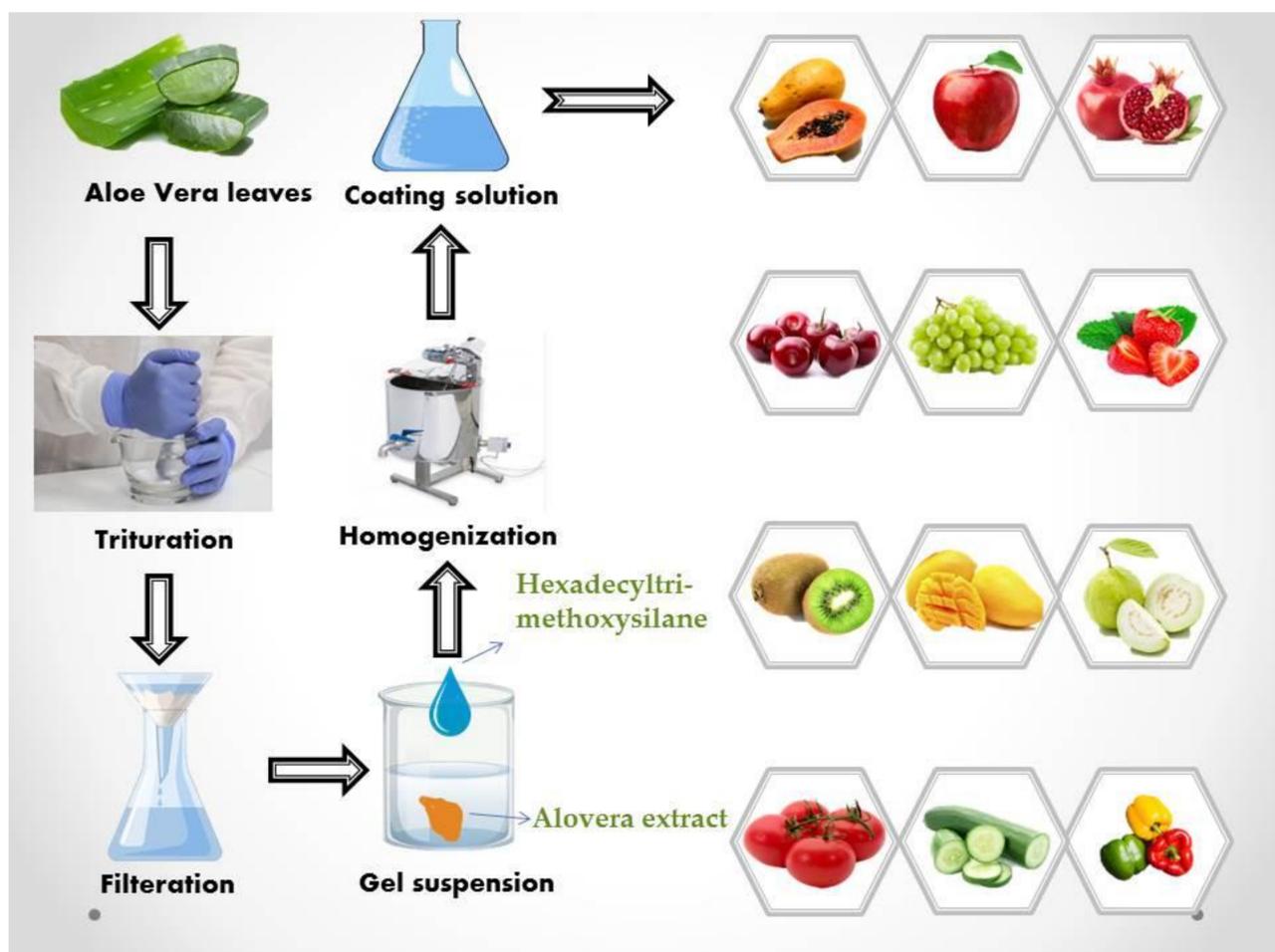
## 4. Postharvest Quality of Fruits and Vegetables and the Role of Plant Extracts

Fruits and vegetables, for their decent palate and nutrient richness such as polyphenolic compounds, vitamins, and organic acids, are considered to be preferred food for humans worldwide [76]. These products undergo numerous hasty fluctuations in their taste and nutrients, thus influencing consumer acceptance during postharvest storage, which ultimately results in the loss of fresh produce [76]. Senescence is a stage where anabolic processes give way to the catabolic process that is responsible for the decay of fresh produce. That leads to the undesirable modification in the postharvest quality and composite progression that is prejudiced by both endogenous and exogenous environments [77]. The significance of fresh fruits and vegetables is calculated based on mass. Due to shrinkage, a mass decline has adverse effects and massive financial losses [78]. With the perishable nature of most fruits, it is of utmost importance to seek for environment-friendly treatments to mend the quality of such products [11]. Plant extracts have recently gained a great deal of attention due to their various health benefits and possible agricultural implementations. Several previous studies have shown that the treatment of plant extracts enhances fruits and vegetables' durability after harvest and increases shelf life. Postharvest treatments for plant extract retain higher non-enzymatic antioxidant activity, increased antioxidant capacity, hormone bio-synthesis regulation, and delayed breakdown of the cell wall [56].

### 4.1. Aloe Vera Extract: Effect on Postharvest Quality of Fruits and Vegetables

For the treatment of banana fruit, aloe vera extract delays the vicissitudes in loss of weight, titratable acidity, accumulation of soluble solids, and firmness. Moreover, spraying aloe vera gel improves the total phenolic contents and total antioxidant activities of banana fruit [79,80]. Spraying of table grapes (*Vitis vinifera*) of Shahroudi cultivar with aloe vera has an optimistic result on the postharvest quality and improves the characteristics of the weight loss, total soluble solids, berry firmness, enzymatic activity, and titratable acidity [81]. *Aloe vera* gel treatment is perceived to be an environment-friendly non-chemical substitute method for the handling of litchi fruit after harvest because it prevents browning, which would be the key restriction on the quality of litchi fruit after harvest and the selling of litchi fruit [82]. Aloe gel curtails the decay prevalence and lessens the loss of weight, rate of respiration, and ethylene production to a larger range. It also suppresses diseases and preserves the expected properties of mango fruit during postharvest storage [83]. Higher

pH, soluble solids concentration, ascorbic acid, titratable acidity, total carotenoid content, total flavonoid content, and total phenolic content are preserved by treatment of papaya fruit covered with *Aloe vera* gel compared to uncoated papaya fruits that decomposed during 12 days of storing [84]. Pomegranate spraying with 100% aloe vera extract is the greatest operative for the reduction of physiological losses in terms of weight, almost 50% less reduction compared to untreated ones. *Aloe vera* extract-treated pomegranate fruits show reduced total soluble solids to the acid ratio (32.17%) and pointedly maximum juice contents (47.17%), ascorbic acid (12.82 mg/100 g), and anthocyanin (13.98 mg/100 g) of the fruits as well as the maximum organoleptic rating [85]. Sapodilla fruit coated with aloe vera keeps tall firmness and titratable acidity levels compared to uncoated fruits [79]. After harvesting, aloe vera on the blueberry surface offers an extra shield to minimize postharvest microbial spoilage as well as to decrease the loss of water, the two key factors of postharvest blueberry loss in quality. A schematic diagram of aloe vera extract utilization is shown in Figure 1.



**Figure 1.** *Aloe vera* extract as a spraying material.

#### 4.2. Lemongrass Extract: Effect on Postharvest Quality of Fruits and Vegetables

It is suggested that lemongrass essential oil sustains the quality traits of fruits throughout postharvest handling. There is a positive impact of lemongrass essential oil [86] on the postharvest quality characteristics of apple cultivars ‘Granny Smith’ and ‘Pink Lady’. The appraised phenolic contents and antioxidant activity of fruits convey health benefits to consumers [26]. Lemongrass essential oil spraying on blackberries in combination with micro-fibrillated cellulose at concentrations of 0.2, 0.4, and 0.6% are effective in protecting blackberry fruits’ freshness and dropping the color reversal while in stores [87]. Applica-

tions of lemongrass essential oil significantly preserved the physical quality parameters of the cucumber at an ambient temperature of  $28 \pm 2$  °C during the postharvest storage [88]. Guava fruit treated with lemongrass essential oil preserves and maintains its physicochemical characteristics during postharvest handling [89].

#### 4.3. Neem Extract: Effect on Postharvest Quality of Fruits and Vegetables

The treatment effect of neem leaf extract (20% or 40%) on the postharvest quality of the banana has a significant effect on the physicochemical parameters of the banana fruit [90]. Neem-extract-treated mangoes show expressively the lowest physiological losses in weight. Such treatment suggestively improves and maintains the better physic-chemical quality of Amrapali mango fruit [91]. The neem leaves extract treatment at 5% concentration imparts the best positive effect on the external quality of papaya fruit. Papaya Formosa fruits treated with neem extract keep their good quality during postharvest handling and storage [92]. This postharvest procedure of applying neem extract to the pitaya fruit has a massive impact on the freshness of pitaya in terms of commercial exploitation with the best postharvest quality and good taste with high antioxidants [93].

### 5. Plant Extracts' Influence on Postharvest Diseases and Shelf-Life Extension

The food manufacturing sector is always in front of the challenge of food storage problems and intensifying the life of fresh fruits and vegetables after harvest. Foodborne pathogens are one of the chief agents and are responsible for the spoilage of food and the worsening of consumer health [94]. Table 1 shows the influence of plant extracts effect on the postharvest quality of different fruits. Fruits and vegetables are living creatures, and during breathing, they continuously use oxygen and produce carbon dioxide. The metabolism of substrates such as proteins, fats, and organic acids also with carbohydrates takes place in the respiration phase. When substrates and carbohydrates are metabolized, then it becomes challenging to replenish them since the vegetable or fruit is removed from the plant [95].

**Table 1.** Plant extracts' effect on postharvest quality.

Plant Extract	Fruits	Treatments	Results	Reference
	Sapodilla ( <i>Manilkara zapota</i> L.)	<i>Fagonia indica</i> 1% + aloe vera gel 100%	<ul style="list-style-type: none"> <li>• Radical scavenging activity improved</li> <li>• Maintained total phenolic and flavonoids</li> <li>• Higher ascorbic acid maintained</li> <li>• No negative effect was found on sensory attributes</li> <li>• Shelf life improved for 12 days</li> </ul>	[79]
	Guava ( <i>Psidium guajava</i> )	10% garlic extract + 100% aloe vera gel	<ul style="list-style-type: none"> <li>• Higher total flavonoid</li> <li>• Enhance shelf life</li> </ul>	[96]
<i>Aloe vera</i> ( <i>A. barbadensis</i> Miller)	Grapes ( <i>Vitis</i> )	20% aloe vera	<ul style="list-style-type: none"> <li>• Reduce moisture loss</li> <li>• Provide a good gloss appearance</li> <li>• Reduce fungal infection</li> <li>• Enhance shelf life</li> </ul>	[97]
	Banana ( <i>Musa acuminata</i> )	Aloe vera gel 0.05% + garlic oil 0.1%	<ul style="list-style-type: none"> <li>• No change in weight loss</li> <li>• Delay firmness, soluble solids, and titratable acidity</li> <li>• Enhanced total phenolic contents and total antioxidant</li> </ul>	[85]
	Litchi ( <i>Litchi chinensis</i> )	Aloe vera gel 50%	<ul style="list-style-type: none"> <li>• Maintained postharvest quality</li> <li>• Reduced browning index and weight loss</li> <li>• Higher ascorbic acid content</li> <li>• Increase total phenolic concentration</li> </ul>	[82]

Table 1. Cont.

Plant Extract	Fruits	Treatments	Results	Reference
	Mango ( <i>M. indica</i> )	1% chitosan + 1% aloe vera gel	<ul style="list-style-type: none"> <li>Prevent from decay</li> <li>Reduced weight loss and ethylene production</li> <li>Maintained the natural properties of mango</li> </ul>	[83]
	Papaya ( <i>Carica papaya</i> )	50% aloe vera gel	<ul style="list-style-type: none"> <li>Enhance phenolic content (41.75 mg/100 g)</li> <li>Shelf life enhances up to 9 days</li> </ul>	[84]
	Blueberry ( <i>Vaccinium corymbosum</i> )	Chitosan 0.5% + aloe vera liquid fraction 0.5%	<ul style="list-style-type: none"> <li>Microbiological growth reduced</li> <li>50% water loss minimized</li> <li>Mold contamination appears with a gap of 9 days</li> <li>Shelf life improved for 5 days</li> </ul>	[34]
	Object with Gram-Positive bacteria	30 µL <i>Aloe vera</i> leaf extract	<ul style="list-style-type: none"> <li>Inhibition of <i>B. subtilis</i> (15 mm)</li> <li>Inhibition of <i>B. cereus</i> (13 mm)</li> <li>Inhibition of <i>B. megaterium</i> (14.5 mm)</li> <li>Inhibition of <i>Streptococcus pyogenes</i> (13 mm)</li> <li>Inhibition of <i>Staphylococcus aureus</i> (14 mm)</li> </ul>	[98]
	Object with Gram-Negative bacteria	30 µL <i>Aloe vera</i> leaf extract	<ul style="list-style-type: none"> <li>Inhibition of <i>E. coli</i> and <i>Agrobacterium tumefaciens</i> (18 mm)</li> </ul>	
	Object with Gram-Positive bacteria	30 µL <i>Aloe vera</i> root extract	<ul style="list-style-type: none"> <li>Inhibition of <i>Bacillus subtilis</i>, <i>B. megaterium</i>, and <i>Enterococcus faecalis</i> (16 mm)</li> <li>Inhibition of <i>B. cereus</i> (13.5 mm)</li> </ul>	
	Object with Gram-Negative bacteria	30 µL <i>Aloe vera</i> root extract	<ul style="list-style-type: none"> <li>Inhibition of <i>Agrobacterium tumefaciens</i> (17.5 mm)</li> <li>Inhibition of <i>E. coli</i> (16 mm)</li> </ul>	
	Object with fungus	30 µL <i>Aloe vera</i> leaf extract	<ul style="list-style-type: none"> <li>Inhibition of <i>Fusarium oxysporum</i> (18.5 mm)</li> <li>Inhibition of <i>Aspergillus niger</i> (18 mm)</li> </ul>	
	Object with fungus	30 µL <i>Aloe vera</i> root extract	<ul style="list-style-type: none"> <li>Minimum but good results for inhibition of <i>Fusarium oxysporum</i> and <i>Aspergillus niger</i></li> </ul>	
	Banana ( <i>Musa paradisiaca</i> Linn.)	1.0% lemongrass oil + 2.0% neem oil	<ul style="list-style-type: none"> <li>Reduce fungal growth</li> <li>Inhibit the <i>Colletotrichum musae</i> which cause Anthracnose in Banana fruit</li> </ul>	[99]
	Banana ( <i>M. paradisiaca</i> Linn.)	41.29% lemongrass oil + 32.15% geraniol	<ul style="list-style-type: none"> <li>Effective against <i>C. musae</i>, <i>Fusarium incarnatum</i>, and <i>F. verticillioides</i></li> <li>Inhibited mycelial growth and conidia germination</li> </ul>	[100]
	Guavas ( <i>Psidium guajava</i> L.)	Chitosan + 1.5% essential oil	<ul style="list-style-type: none"> <li>Inhibition of anthracnose lesions</li> <li>Enhance the stability of the guavas fruit for up to 12 days</li> </ul>	[101]
Lemongrass oil ( <i>Cymbopogon citratus</i> )	Apple ( <i>Malus domestica</i> )	Thermal fogging −0.5 °C + lemongrass essential oil 1.5% + control atmosphere	<ul style="list-style-type: none"> <li>Lower titratable acidity and total soluble solid content</li> <li>Higher total phenolic content and radical scavenging activity</li> </ul>	[102]
	Blackberry ( <i>Rubus fruticosus</i> )	Lemongrass essential oil 1000 ppm + micro fibrillated cellulose 0.4%	<ul style="list-style-type: none"> <li>No changes in total soluble solids</li> </ul>	[103]

Table 1. Cont.

Plant Extract	Fruits	Treatments	Results	Reference
Neem ( <i>Azadirachta indica</i> ) (LD50 ≥ 5000 mg/kg)	Guava ( <i>Psidium guajava</i> )	0.4 kGy $\gamma$ irradiation + lemongrass oil 2%	<ul style="list-style-type: none"> <li>Reduced decay and water loss percentages</li> <li>Controlled total soluble solid, titratable acidity, and vitamin C decrements</li> <li>Increased fruit softness</li> </ul>	[89]
	Orange ( <i>Citrus sinensis</i> L. osbeck)	Red thyme oil 6.7 $\mu$ L/L + essential oil	<ul style="list-style-type: none"> <li><i>Penicillium</i> decay</li> <li>Inhibit the production of spore</li> <li>Extend shelf life up to 12 days</li> </ul>	[104]
	Banana ( <i>M. paradisiaca</i> Linn.)	40% neem leaf extract	<ul style="list-style-type: none"> <li>Minimal color change</li> <li>No disease incidence</li> <li>Lower reduction in titratable acidity</li> <li>Enhance longer shelf life 8.33 days</li> </ul>	[90]
	Mango ( <i>Mangifera indica</i> )	40% of neem leaf extract + 40% banana pulp	<ul style="list-style-type: none"> <li>Slower changes in color (score 2.93)</li> <li>Firmness (score 2.77)</li> <li>Less disease severity (score 3.57)</li> <li>Disease incidence (60.00%)</li> <li>Lower loss in weight (35.17%)</li> <li>Longer shelf life (10.25 Days)</li> </ul>	[105]
	Mango ( <i>M. indica</i> )	Crude water extract of neem 30%	<ul style="list-style-type: none"> <li>Control mango fruit rot incidence</li> </ul>	[106]
Moringa ( <i>Moringa oleifera</i> )	Tomatoes ( <i>Lycopersicon esculentum</i> Mill.)	25% neem leaf extract	<ul style="list-style-type: none"> <li>Enhance shelf life</li> <li>Effectively reduce weight loss by 55–60%</li> <li>Change in titratable acidity 20–67%</li> <li>Total soluble solubility 2.8–6.9</li> </ul>	[107]
	Papaya ( <i>C. papaya</i> )	5 and 10% neem leaf extracts	<ul style="list-style-type: none"> <li>5% had the best effects on external quality</li> <li>Inhibit the growth of phytopathogenic fungi</li> <li>Enhance shelf life for 12 days</li> </ul>	[92]
	Avocado ( <i>Persea Americana</i> )	1% carboxyl methylcellulose + 2% moringa leaf extract	<ul style="list-style-type: none"> <li>Lower mass loss, ethylene production, and respiration rate</li> <li>Inhibition of gloeosporioides and <i>A. alternata</i></li> <li>Higher antimicrobial activity</li> <li>Prolongs the shelf-life</li> </ul>	[26]
Green tea ( <i>Camellia sinensis</i> )	Potato ( <i>Solanum tuberosum</i> )	50 mL/L green tea extract	<ul style="list-style-type: none"> <li>Controlled browning in fresh-cut potatoes</li> <li>Prolong shelf life for 14 days</li> </ul>	[108]
Clove ( <i>Syzygium aromaticum</i> )	Potato ( <i>S. tuberosum</i> )	1–25 g GAE/L clove extract	<ul style="list-style-type: none"> <li>Higher total phenolic content</li> <li>Improve antioxidant activity</li> <li>&gt;50% inhibition of potato polyphenol oxidase</li> </ul>	[108]
Pomegranate peel ( <i>Punica granatum</i> )	Apricot ( <i>Prunus armeniaca</i> )	Chitosan + 1% pomegranate peel extract	<ul style="list-style-type: none"> <li>Reduced decay percentage and weight loss</li> <li>Effectively retained DPPH radical scavenging activity</li> <li>Improve firmness</li> <li>Enhance shelf life</li> </ul>	[109]
Pomegranate peel extract ( <i>Punica granatum</i> )	Sweet cherry fruit ( <i>Prunus avium</i> )	CaSO <sub>4</sub> 1% + Pomegranate peel extract 400 ppm	<ul style="list-style-type: none"> <li>Preserved fruit colour during storage</li> <li>Enhance shelf life</li> </ul>	[110]
<i>Prosopis juliflora</i> water-soluble leaf ethanolic	Strawberry ( <i>Fragaria x ananassa</i> )	1% chitosan + <i>Prosopis juliflora</i> leaf extract	<ul style="list-style-type: none"> <li>Maintenance of firmness</li> <li>Improve total soluble solids</li> <li>Inhibit the microbial load</li> <li>Lower percent weight loss</li> <li>Increase total antioxidant levels</li> </ul>	[111]

Table 1. Cont.

Plant Extract	Fruits	Treatments	Results	Reference
Blackberry ( <i>Morus nigra</i> L.)	Cherry tomato ( <i>Solanum Lycopersicum</i> , L.)	Blackberry ( <i>Morus nigra</i> L.) anthocyanin rich-extract 30%	<ul style="list-style-type: none"> <li>Maintain constant fruit weight and firmness</li> <li>Increase shelf life</li> </ul>	[112]
Thyme ( <i>Thymus vulgaris</i> )	Avocado ( <i>Persea Americana</i> )	Applied 2000 ppm	<ul style="list-style-type: none"> <li>Decrease lesion expansion</li> <li>Increase firmness</li> <li>Enhance shelf life</li> </ul>	[113]
Guava Leaf ( <i>Myrtaceae</i> ) and Lemon extract ( <i>C. limon</i> )	banana cv. Sabri ( <i>Musa sapientum</i> L.)	20% Guava leaf and 15% Lemon extract	<ul style="list-style-type: none"> <li>Enhance shelf life for long-term storage</li> </ul>	[90]

There is a rising awareness about the use of natural and safe plant-based preservatives for the prolongation of fruits and vegetables to substitute harmful chemicals to combat the challenges of preserving food with less or no harm to consumer health [114]. Fruits and vegetables are consumed processed or fresh according to their various health benefits [95]. The growing claim for pesticide-free food has pushed the research towards the era of plant-based extracts as a resolute substitute for hazardous pesticides [18]. Natural polymers have various advantages compared to synthetic polymers due to their biocompatibility, biodegradability, and compliance with chemical and biochemical modifications [115]. A schematic diagram of plant extract utilization against postharvest decay is shown in Figure 2.

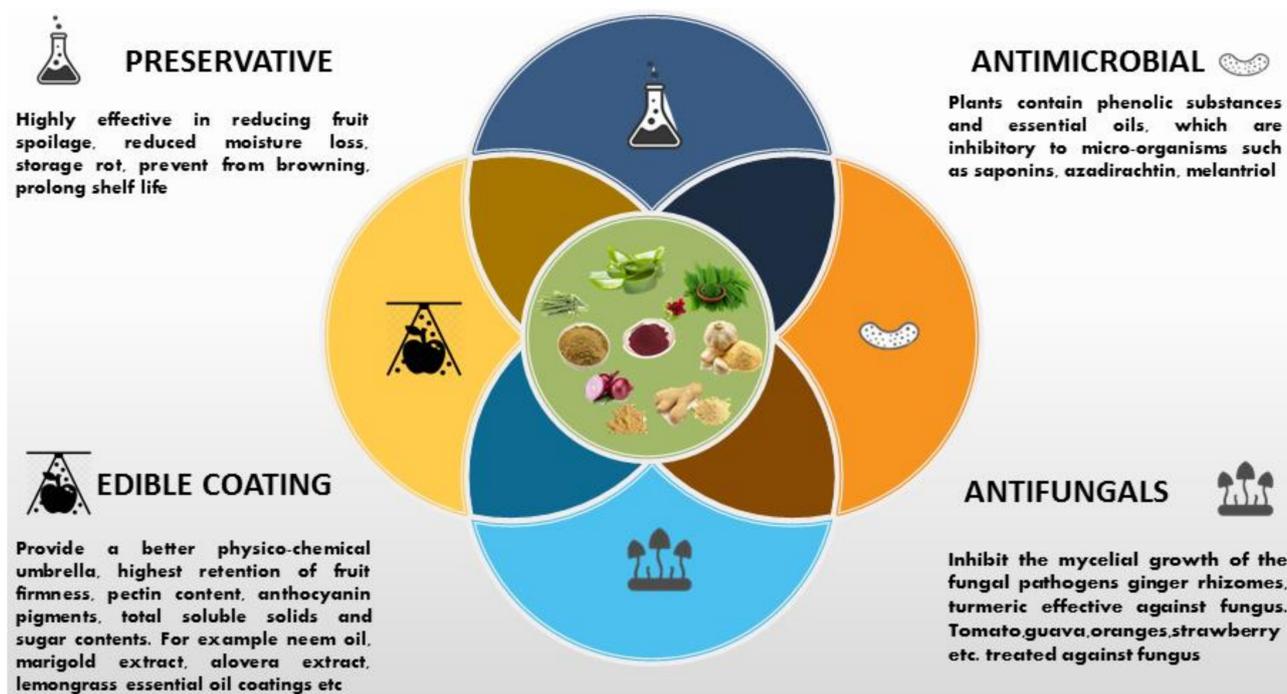


Figure 2. Plant extracts utilization against postharvest problems.

### 5.1. Aloe Vera Extract: Effect on Postharvest Diseases and Shelf-Life

*Aloe* gel spraying can be used to regulate and maintain the inhibition of banana fruit metabolism, leading to anthracnose disease resistance. An alternative technique to synthetic pesticides to combat anthracnose disease and preserve the postharvest quality of banana fruit can be maintained by *Aloe* gel spraying [79]. Chitosan-based aloe vera extract edible spraying lengthens the shelf-life of Blueberries up to 5 days, indicating that the chitosan and aloe vera liquid combination potentiates the shelf-life extension of fruits. *Aloe* gel positively influences storage life and table grapes' postharvest quality. *Aloe vera* extract

application has proved to be an eco-friendly alternative technique to synthetic chemical treatment for the postharvest quality maintenance of litchi fruit. *Aloe vera* gel-coated fruits and vegetables show reduced postharvest browning, the leading limitation for prolonged storage life and presentation of litchi [82]. Chitosan-based aloe vera gel applications prolong the postharvest quality and the storage life of mango fruit [83]. Papaya fruits coated with aloe vera extract exhibit a significant delay in ripening, stifled the growth of fungus, and preserved the postharvest papaya fruits' quality in storage for up to 15 days [84]. The spraying of *Aloe vera* extract considerably expands the storage life along with the improved retentive fruit quality features under normal storage conditions [82]. In addition, the aloe vera antifungal compound provides an innovative way of enhancing the protection and shelf-life of blueberries without the need for synthetic substances in edible films or spraying. *Aloe vera* fractions may be an enticing healthier solution to fungi that invade fruit and vegetables, avoid unnecessary use of additives, and thus help to prevent health and environmental issues from occurring.

### 5.2. Lemongrass Extract: Effect on Postharvest Diseases and Shelf-Life

Lemongrass essential oil comprises numerous antifungal properties and is an effective and workable choice in postharvest treatment, as it interposes the growth of microorganisms. Lemongrass oil at 1.0% concentration was found to be a very effective postharvest treatment against anthracnose without phytotoxicity effect on banana fruits [99]. Lemongrass essential oil treatment inhibits the crown rot pathogens of banana fruit. Lemongrass oil shows an antifungal effect in contradiction to *C. musae*, *Fusarium incarnatum*, and *F. verticillioides* at 475, 350, and 600  $\mu\text{L/L}$ , respectively [100]. The potential of lemongrass essential oil for enhancing the shelf life can be utilized on blackberries. The application of essential oil reduces the deterioration of fruit and prolongs the storage life for longer consumption periods [65]. Guava fruit treated with lemongrass extract shows a great effect on the management of *Colletotrichum gloeosporioides*. The inhibition of mycelial growth and sporulation of the pathogen can be observed at different concentrations of the plant extracts. However, complete inhibition was achieved at an 8% concentration [101]. Applying lemongrass essential oil vapors at different concentrations has significant potential to control the *Penicillium* decay of orange [104]. Lemongrass extract has antifungal activity against *A. niger* and *C. musae* [116].

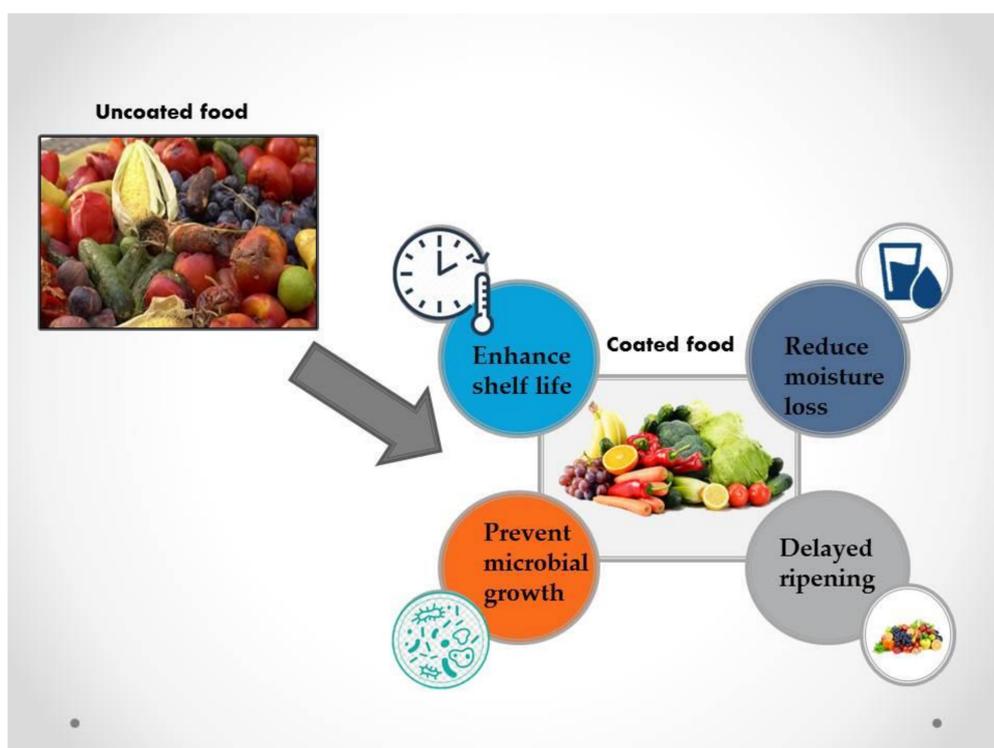
### 5.3. Neem Extract: Effect on Postharvest Diseases and Shelf-Life

Neem extract facilitates the storage period of banana fruit. Banana fruit applied with neem extract show good storage quality. The application of 40% neem extract enhances the shelf life of banana fruit for a considerably longer period [90]. Neem extract can be used to successfully manage postharvest losses due to postharvest diseases of fresh produce in other tropical and subtropical fruits. Application of neem extract inhibits the mycelial growth of pathogens *Neofusicoccum parvum*, *Lasioidiplodia theobromae*, *Aspergillus flavus*, *Botrytis cinerea*, and *A. niger* in mangoes and longer the shelf life of fruit. Postharvest treatments of mango fruit with neem extract meaningfully affect the microbial parameters of mango fruit. Treatment of neem extract encourages storage stability and enhances the period of storage [106].

### 5.4. Other Plant Extracts and Their Effect on Postharvest Quality and Shelf Life

The efficacy of the edible spraying of the soy and wheat gluten-based plant protein extract preserves the consistency and shelf life of the strawberry postharvest quality. This treatment maintains ascorbic acid, which is related to the contents of vitamin C of the strawberry fruit, the chief component to determine the activity of the antioxidants of strawberry [78]. Applying and spraying seed/leaf extracts of moringa leaf and 1% carboxymethylcellulose on avocado fruit cultivars 'Hass' and 'Gem' has a great influence on postharvest quality and shelf life. Throughout the storage period, treatment decreases ethylene output, respiration rate, and greater firmness compared to un-coated fruit. This

application suggests a decreased loss of moisture, the occurrence of disease, and the severity of the coated fruit. Spraying treatments extend the shelf-life and preserve the consistency of the two avocado cultivars after harvest. In addition, moringa ethanol extract had significant antimicrobial activity and was far more effective as compared to methanolic extracts in hindering foodborne pathogens. Organic postharvest treatment for 'Hass' and 'Gem' avocado could be a 1% carboxymethylcellulose edible spraying comprising moringa leaf/seed extracts [117]. The *Penicillium digitatum* mycelial growth proliferation and in vitro sporulation and green mold on oranges are reduced by volatile substances of brassica sachets and extracts. With canola sachets, green mold control is achieved, and its conjunction with thermotherapy does not seem to improve the condition. Canola sachets have a great capacity as potential prevention for green mold and should therefore be tested under conditions of bacterial invasion as well as other postharvest disorders as well [118]. Dukung anak extrude crude or turmeric extracts can be used as a bio fungicide to control postharvest anthracnose in dragon fruit at a total concentration of 10.0 g. Furthermore, fruits treated with ginger and turmeric can cure the original color, aroma, and skin of the fruits and vegetables [119]. The application of edible spraying and plant extracts for pre-storage can be effective in preventing maturation and ensuring the integrity of guava. The mixture of gum Arabic and garlic extract suppressed weight loss, skin browning, disease progression, and prolonged shelf life of guava fruits under environmental conditions. Overall, the combined treatment of Arabic gum and garlic extract still preserves the physiological, chemical, and sensory consistency of the guava fruit. Such treatment of garlic extract and gum Arabic may also be considered an efficient treatment for the extended storage life and the consistency of guava fruit preservation [96]. A schematic diagram of the beneficial effects of spraying on fruit quality is shown in Figure 3.



**Figure 3.** Beneficial effects of spraying on fruits and vegetables.

Many notable findings strongly suggest the noteworthy function of plant oligosaccharides in the sustainability of fruit after harvest, which places importance on oligosaccharide care, retaining the consistency of fruit, and preserving the life of storage by maintaining various physicochemical properties. Plant oligosaccharides have enhanced the function

of antioxidants, the activity of enzymes relevant to disease defense, and control of the maturation of gene expression [56]. The combination of treatments with chitosan, oligosaccharide, and salicylic acid could substantially delay the maturation of apricots. In addition, during storage, the application of chitosan, oligosaccharide, and salicylic acid retained postharvest consistency characteristics of the 'Xiaobai' apricot, involving latency in the increasing rate of decay, loss of firmness, and a decline in total soluble solids and titratable acidity content, and color shift [120]. The taste, odor, and color of some plant extracts used for the preservation of food might change their organoleptic properties [121]. However, in some cases, it is vice versa, like extracts improve the quality of the food [122]. One can also tackle this limiting factor of plant extracts by removing the coloring agents from extracts and using the specified dose of plant extracts [123].

## 6. Conclusions

The continuous growth of the population has driven the increased demand for fresh fruits and vegetables; that is why plant-based extract could be a decent alternative source to the chemical synthetic pesticides for preserving the postharvest quality of fresh fruits and vegetables and for the enhancement of their shelf life. Chemical pesticides have been used for a long time in the agriculture sector for the destruction of pests exert hazardous consequences on both environment and human health. The research explored the health hazards of these chemicals. Natural alternatives to chemicals are safer and perform the same role as pest control and postharvest quality maintenance. *Aloe vera*, lemongrass, and neem extract are economical sources of diverse, high-added-value materials that exhibit the potential to maintain the postharvest quality of fruits and vegetables and good natural alternatives to hazardous chemicals as well. These promising natural extracts can be an excellent source alternative to chemical pesticides and preservatives to protect fresh fruits and vegetables from spoilage.

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## References

1. Mahajan, P.V.; Caleb, O.J.; Singh, Z.; Watkins, C.B.; Geyer, M. Postharvest Treatments of Fresh Produce. *Philos. Trans. A Math. Phys. Eng. Sci.* **2014**, *372*, 20130309. [[CrossRef](#)]
2. Roobab, U.; Abida, A.; Chacha, J.S.; Athar, A.; Madni, G.M.; Ranjha, M.M.A.N.; Rusu, A.V.; Zeng, X.-A.; Aadil, R.M.; Trif, M. Applications of Innovative Non-Thermal Pulsed Electric Field Technology in Developing Safer and Healthier Fruit Juices. *Molecules* **2022**, *27*, 4031. [[CrossRef](#)] [[PubMed](#)]
3. Ncama, K.; Magwaza, L.S.; Mditshwa, A.; Tesfay, S.Z. Plant-Based Edible Coatings for Managing Postharvest Quality of Fresh Horticultural Produce: A Review. *Food Packag. Shelf Life* **2018**, *16*, 157–167. [[CrossRef](#)]
4. Maduwanthi, S.D.T.; Marapana, R.A.U.J. Induced Ripening Agents and Their Effect on Fruit Quality of Banana. *Int. J. Food Sci.* **2019**, *2019*, 2520179. [[CrossRef](#)] [[PubMed](#)]
5. Riaz, A.; Aadil, R.M.; Amoussa, A.M.O.; Bashari, M.; Abid, M.; Hashim, M.M. Application of Chitosan-Based Apple Peel Polyphenols Edible Coating on the Preservation of Strawberry (*Fragaria ananassa* Cv Hongyan) Fruit. *J. Food Process. Preserv.* **2021**, *45*, e15018. [[CrossRef](#)]
6. Elik, A.; Yanik, D.K.; Guzelsoy, N.A.; Yavuz, A.; Gogus, F. Strategies to Reduce Post-Harvest Losses for Fruits and Vegetables. *Strategies* **2019**, *5*, 29–39. [[CrossRef](#)]

7. Tesfay, S.Z.; Magwaza, L.S.; Mbili, N.; Mditshwa, A. Carboxyl Methylcellulose (CMC) Containing Moringa Plant Extracts as New Postharvest Organic Edible Coating for Avocado (*Persea americana* Mill.) Fruit. *Sci. Hortic.* **2017**, *226*, 201–207. [[CrossRef](#)]
8. Yildiz, G.; Izli, G.; Aadil, R.M. Comparison of Chemical, Physical, and Ultrasound Treatments on the Shelf Life of Fresh-Cut Quince Fruit (*Cydonia oblonga* Mill.). *J. Food Process. Preserv.* **2020**, *44*, e14366. [[CrossRef](#)]
9. Karwal, P.; Mittal, P.; Nagar, G.; Singh, A.; Singh, I.K. Effects of Pesticides on Human Physiology, Genetics, and Evolution. *Emerg. Contam. Environ. Challenges Sustain. Pract.* **2022**, *2022*, 287–310. [[CrossRef](#)]
10. Hassaan, M.A.; El Nemr, A. Pesticides Pollution: Classifications, Human Health Impact, Extraction and Treatment Techniques. *Egypt. J. Aquat. Res.* **2020**, *46*, 207–220. [[CrossRef](#)]
11. Zhang, W.; Cao, J.; Fan, X.; Jiang, W. Applications of Nitric Oxide and Melatonin in Improving Postharvest Fruit Quality and the Separate and Crosstalk Biochemical Mechanisms. *Trends Food Sci. Technol.* **2020**, *99*, 531–541. [[CrossRef](#)]
12. Choi, W.S.; Singh, S.; Lee, Y.S. Characterization of Edible Film Containing Essential Oils in Hydroxypropyl Methylcellulose and Its Effect on Quality Attributes of ‘Formosa’ Plum (*Prunus salicina* L.). *LWT* **2016**, *70*, 213–222. [[CrossRef](#)]
13. Kumar, P.; Sethi, S.; Sharma, R.R.; Srivastav, M.; Varghese, E. Effect of Chitosan Coating on Postharvest Life and Quality of Plum during Storage at Low Temperature. *Sci. Hortic.* **2017**, *226*, 104–109. [[CrossRef](#)]
14. Thakur, R.; Pristijono, P.; Golding, J.B.; Stathopoulos, C.E.; Scarlett, C.J.; Bowyer, M.; Singh, S.P.; Vuong, Q.V. Development and Application of Rice Starch Based Edible Coating to Improve the Postharvest Storage Potential and Quality of Plum Fruit (*Prunus salicina*). *Sci. Hortic.* **2018**, *237*, 59–66. [[CrossRef](#)]
15. Arnon-Rips, H.; Poverenov, E. Improving Food Products’ Quality and Storability by Using Layer by Layer Edible Coatings. *Trends Food Sci. Technol.* **2018**, *75*, 81–92. [[CrossRef](#)]
16. Kapeleka, J.A.; Sauli, E.; Ndakidemi, P.A. Pesticide Exposure and Genotoxic Effects as Measured by DNA Damage and Human Monitoring Biomarkers. *Int. J. Environ. Health Res.* **2021**, *31*, 805–822. [[CrossRef](#)]
17. Sabarwal, A.; Kumar, K.; Singh, R.P. Hazardous Effects of Chemical Pesticides on Human Health—Cancer and Other Associated Disorders. *Environ. Toxicol. Pharmacol.* **2018**, *63*, 103–114. [[CrossRef](#)] [[PubMed](#)]
18. Raheison, C.; Baldi, I.; Pouquet, M.; Berteaud, E.; Moesch, C.; Bouvier, G.; Canal-Raffin, M. Pesticides Exposure by Air in Vineyard Rural Area and Respiratory Health in Children: A Pilot Study. *Environ. Res.* **2019**, *169*, 189–195. [[CrossRef](#)]
19. Kim, K.H.; Kabir, E.; Jahan, S.A. Exposure to Pesticides and the Associated Human Health Effects. *Sci. Total Environ.* **2017**, *575*, 525–535. [[CrossRef](#)]
20. Plant Extracts Market by Type (Phytomedicines & Herbal Extracts, Spices, Essential Oils, Flavors & Fragrances), Application (Pharmaceutical & Dietary Supplements, Food & Beverages, Cosmetics), Sources, and Region—Forecast to 2026. Available online: [https://www.researchandmarkets.com/reports/5324736/plant-extracts-market-by-type-phytomedicines-and?utm\\_source=GNOM&utm\\_medium=PressRelease&utm\\_code=kqj2z&utm\\_campaign=1542829+-+Global+Plant+Extracts+Market+\(2021+to+2026\)+-+Growing+Trend+of+Veganism+and+](https://www.researchandmarkets.com/reports/5324736/plant-extracts-market-by-type-phytomedicines-and?utm_source=GNOM&utm_medium=PressRelease&utm_code=kqj2z&utm_campaign=1542829+-+Global+Plant+Extracts+Market+(2021+to+2026)+-+Growing+Trend+of+Veganism+and+) (accessed on 21 July 2022).
21. Dawlatana, M. Science and Technology for Sustainable Development. *Bangladesh J. Sci. Ind. Res.* **2019**, *54*, 1–134. [[CrossRef](#)]
22. Bose, S.K.; Howlader, P.; Jia, X.; Wang, W.; Yin, H. Alginate Oligosaccharide Postharvest Treatment Preserve Fruit Quality and Increase Storage Life via Abscisic Acid Signaling in Strawberry. *Food Chem.* **2019**, *283*, 665–674. [[CrossRef](#)] [[PubMed](#)]
23. Elsherbiny, E.A.; Amin, B.H.; Baka, Z.A. Efficiency of Pomegranate (*Punica granatum* L.) Peels Extract as a High Potential Natural Tool towards Fusarium Dry Rot on Potato Tubers. *Postharvest Biol. Technol.* **2016**, *111*, 256–263. [[CrossRef](#)]
24. Kazemi, M.; Karim, R.; Mirhosseini, H.; Abdul Hamid, A. Optimization of Pulsed Ultrasound-Assisted Technique for Extraction of Phenolics from Pomegranate Peel of Malas Variety: Punicalagin and Hydroxybenzoic Acids. *Food Chem.* **2016**, *206*, 156–166. [[CrossRef](#)] [[PubMed](#)]
25. Kharchoufi, S.; Licciardello, F.; Siracusa, L.; Muratore, G.; Hamdi, M.; Restuccia, C. Antimicrobial and Antioxidant Features of ‘Gabsi’ Pomegranate Peel Extracts. *Ind. Crops Prod.* **2018**, *111*, 345–352. [[CrossRef](#)]
26. Mbili, N.C.; Lennox, C.L.; Vries, F.A.; Opara, U.L. The Effects of Lemon, Lime and Lemongrass Essential Oils on Quality Attributes of Apples after Controlled Atmosphere Storage. *Acta Hortic.* **2020**, *1275*, 369–376. [[CrossRef](#)]
27. Proestos, C.; Varzakas, T. Aromatic Plants: Antioxidant Capacity and Polyphenol Characterisation. *Foods* **2017**, *6*, 28. [[CrossRef](#)]
28. Kiokias, S.; Proestos, C.; Oreopoulou, V. Effect of Natural Food Antioxidants against LDL and DNA Oxidative Changes. *Antioxidants* **2018**, *7*, 133. [[CrossRef](#)]
29. Díaz-Montes, E.; Castro-Muñoz, R. Edible Films and Coatings as Food-Quality Preservers: An Overview. *Foods* **2021**, *10*, 249. [[CrossRef](#)] [[PubMed](#)]
30. Paidari, S.; Zamindar, N.; Tahergorabi, R.; Kargar, M.; Ezzati, S.; Shirani, N.; Musavi, S.H. Edible Coating and Films as Promising Packaging: A Mini Review. *J. Food Meas. Charact.* **2021**, *15*, 4205–4214. [[CrossRef](#)]
31. Maan, A.A.; Nazir, A.; Khan, M.K.L.; Ahmad, T.; Zia, R.; Murid, M.; Abrar, M. The Therapeutic Properties and Applications of Aloe Vera: A Review. *J. Herb. Med.* **2018**, *12*, 1–10. [[CrossRef](#)]
32. Parven, A.; Sarker, M.R.; Megharaj, M.; Meftaul, I. Prolonging the Shelf Life of Papaya (*Carica papaya* L.) Using Aloe Vera Gel at Ambient Temperature. *Sci. Hortic.* **2020**, *265*, 109228. [[CrossRef](#)]
33. Nourozi, F.; Sayyari, M. Enrichment of Aloe Vera Gel with Basil Seed Mucilage Preserve Bioactive Compounds and Postharvest Quality of Apricot Fruits. *Sci. Hortic.* **2020**, *262*, 109041. [[CrossRef](#)]
34. Vieira, J.M.; Flores-López, M.L.; de Rodríguez, D.J.; Sousa, M.C.; Vicente, A.A.; Martins, J.T. Effect of Chitosan–Aloe Vera Coating on Postharvest Quality of Blueberry (*Vaccinium corymbosum*) Fruit. *Postharvest Biol. Technol.* **2016**, *116*, 88–97. [[CrossRef](#)]

35. Sogvar, O.B.; Saba, M.K.; Emamifar, A. Aloe Vera and Ascorbic Acid Coatings Maintain Postharvest Quality and Reduce Microbial Load of Strawberry Fruit. *Postharvest Biol. Technol.* **2016**, *114*, 29–35. [[CrossRef](#)]
36. Bill, M.; Sivakumar, D.; Korsten, L.; Thompson, A.K. The Efficacy of Combined Application of Edible Coatings and Thyme Oil in Inducing Resistance Components in Avocado (*Persea americana* Mill.) against Anthracnose during Post-Harvest Storage. *Crop Prot.* **2014**, *64*, 159–167. [[CrossRef](#)]
37. Mani-López, E.; Valle-Vargas, G.P.; Palou, E.; López-Malo, A. Penicillium Expansum Inhibition on Bread by Lemongrass Essential Oil in Vapor Phase. *J. Food Prot.* **2018**, *81*, 467–471. [[CrossRef](#)]
38. Prakash, A.; Baskaran, R.; Vadivel, V. Citral Nanoemulsion Incorporated Edible Coating to Extend the Shelf Life of Fresh Cut Pineapples. *LWT* **2020**, *118*, 108851. [[CrossRef](#)]
39. Jo, W.S.; Song, H.Y.; Song, N.B.; Lee, J.H.; Min, S.C.; Song, K. Bin. Quality and Microbial Safety of ‘Fuji’ Apples Coated with Carnauba-Shellac Wax Containing Lemongrass Oil. *LWT-Food Sci. Technol.* **2014**, *55*, 490–497. [[CrossRef](#)]
40. Yousuf, B.; Srivastava, A.K. Flaxseed Gum in Combination with Lemongrass Essential Oil as an Effective Edible Coating for Ready-to-Eat Pomegranate Arils. *Int. J. Biol. Macromol.* **2017**, *104 Pt A*, 1030–1038. [[CrossRef](#)]
41. Azarakhsh, N.; Osman, A.; Ghazali, H.M.; Tan, C.P.; Mohd Adzahan, N. Lemongrass Essential Oil Incorporated into Alginate-Based Edible Coating for Shelf-Life Extension and Quality Retention of Fresh-Cut Pineapple. *Postharvest Biol. Technol.* **2014**, *88*, 1–7. [[CrossRef](#)]
42. Oms-Oliu, G.; Soliva-Fortuny, R.; Martín-Belloso, O. Edible Coatings with Antibrowning Agents to Maintain Sensory Quality and Antioxidant Properties of Fresh-Cut Pears. *Postharvest Biol. Technol.* **2008**, *50*, 87–94. [[CrossRef](#)]
43. Martínez-Romero, D.; Alburquerque, N.; Valverde, J.M.; Guillén, F.; Castillo, S.; Valero, D.; Serrano, M. Postharvest Sweet Cherry Quality and Safety Maintenance by Aloe Vera Treatment: A New Edible Coating. *Postharvest Biol. Technol.* **2006**, *39*, 93–100. [[CrossRef](#)]
44. Srinivasa, P.; Baskaran, R.; Ramesh, M.; Prashanth, K.H.; Tharanathan, R. Storage Studies of Mango Packed Using Biodegradable Chitosan Film. *Eur. Food Res. Technol.* **2002**, *215*, 504–508. [[CrossRef](#)]
45. Suhag, R.; Kumar, N.; Petkoska, A.T.; Upadhyay, A. Film Formation and Deposition Methods of Edible Coating on Food Products: A Review. *Food Res. Int.* **2020**, *136*, 109582. [[CrossRef](#)]
46. Farina, V.; Gianguzzi, G.; D’Asaro, A.; Mazzaglia, A.; Palazzolo, E. Fruit Production and Quality Evaluation of Four Litchi Cultivars (*Litchi chinensis* Sonn.) Grown in Mediterranean Climate. *Fruits* **2017**, *72*, 203–211. [[CrossRef](#)]
47. Fratianni, A.; Adiletta, G.; Di Matteo, M.; Panfili, G.; Niro, S.; Gentile, C.; Farina, V.; Cinquanta, L.; Corona, O. Evolution of Carotenoid Content, Antioxidant Activity and Volatiles Compounds in Dried Mango Fruits (*Mangifera indica* L.). *Foods* **2020**, *9*, 1424. [[CrossRef](#)]
48. Badar, H.; Ariyawardana, A.; Collins, R. Dynamics of Mango Value Chains in Pakistan. *Pakistan J. Agric. Sci.* **2019**, *56*, 523–530. [[CrossRef](#)]
49. Bibi, F.; Baloch, M.K. Postharvest Quality and Shelf Life of Mango (*Mangifera indica* L.) Fruit as Affected by Various Coatings. *J. Food Process. Preserv.* **2014**, *38*, 499–507. [[CrossRef](#)]
50. Maringgal, B.; Hashim, N.; Mohamed Amin Tawakkal, I.S.; Muda Mohamed, M.T. Recent Advance in Edible Coating and Its Effect on Fresh/Fresh-Cut Fruits Quality. *Trends Food Sci. Technol.* **2020**, *96*, 253–267. [[CrossRef](#)]
51. Pirozzi, A.; Pataro, G.; Donsì, F.; Ferrari, G. Edible Coating and Pulsed Light to Increase the Shelf Life of Food Products. *Food Eng. Rev.* **2021**, *13*, 544–569. [[CrossRef](#)]
52. Maqsood, S.; Benjakul, S.; Abushelaibi, A.; Alam, A. Phenolic Compounds and Plant Phenolic Extracts as Natural Antioxidants in Prevention of Lipid Oxidation in Seafood: A Detailed Review. *Compr. Rev. Food Sci. Food Saf.* **2014**, *13*, 1125–1140. [[CrossRef](#)]
53. Kumar, S.; Singh, N.; Devi, L.S.; Kumar, S.; Kamle, M.; Kumar, P.; Mukherjee, A. Neem Oil and Its Nanoemulsion in Sustainable Food Preservation and Packaging: Current Status and Future Prospects. *J. Agric. Food Res.* **2022**, *7*, 100254. [[CrossRef](#)]
54. Nicolopoulou-Stamati, P.; Maipas, S.; Kotampasi, C.; Stamatis, P.; Hens, L. Chemical Pesticides and Human Health: The Urgent Need for a New Concept in Agriculture. *Front. Public Health* **2016**, *4*, 148. [[CrossRef](#)] [[PubMed](#)]
55. Rani, L.; Thapa, K.; Kanojia, N.; Sharma, N.; Singh, S.; Grewal, A.S.; Srivastav, A.L.; Kaushal, J. An Extensive Review on the Consequences of Chemical Pesticides on Human Health and Environment. *J. Clean. Prod.* **2021**, *283*, 124657. [[CrossRef](#)]
56. Bose, S.K.; Howlader, P.; Wang, W.; Yin, H. Oligosaccharide Is a Promising Natural Preservative for Improving Postharvest Preservation of Fruit: A Review. *Food Chem.* **2021**, *341*, 128178. [[CrossRef](#)]
57. Sola, P.; Mvumi, B.M.; Ogendo, J.O.; Mponda, O.; Kamanula, J.F.; Nyirenda, S.P.; Belmain, S.R.; Stevenson, P.C. Botanical Pesticide Production, Trade and Regulatory Mechanisms in Sub-Saharan Africa: Making a Case for Plant-Based Pesticidal Products. *Food Secur.* **2014**, *6*, 369–384. [[CrossRef](#)]
58. Huang, W.; He, Y.; Xiao, J.; Huang, Y.; Li, A.; He, M.; Wu, K. Risk of Breast Cancer and Adipose Tissue Concentrations of Polychlorinated Biphenyls and Organochlorine Pesticides: A Hospital-Based Case-Control Study in Chinese Women. *Environ. Sci. Pollut. Res. Int.* **2019**, *26*, 32128–32136. [[CrossRef](#)]
59. Ahmed, H.; Abushouk, A.I.; Gabr, M.; Negida, A.; Abdel-Daim, M.M. Parkinson’s Disease and Pesticides: A Meta-Analysis of Disease Connection and Genetic Alterations. *Biomed. Pharmacother.* **2017**, *90*, 638–649. [[CrossRef](#)]
60. Velmurugan, G.; Ramprasath, T.; Swaminathan, K.; Mithieux, G.; Rajendhran, J.; Dhivakar, M.; Parthasarathy, A.; Babu, D.D.V.; Thumburaj, L.J.; Freddy, A.J.; et al. Gut Microbial Degradation of Organophosphate Insecticides-Induces Glucose Intolerance via Gluconeogenesis. *Genome Biol.* **2017**, *18*, 8. [[CrossRef](#)] [[PubMed](#)]

61. Everett, C.J.; Thompson, O.M.; Dismuke, C.E. Exposure to DDT and Diabetic Nephropathy among Mexican Americans in the 1999–2004 National Health and Nutrition Examination Survey. *Environ. Pollut.* **2017**, *222*, 132–137. [[CrossRef](#)]
62. Cano-Sancho, G.; Salmon, A.G.; La Merrill, M.A. Association between Exposure to p,p'-DDT and Its Metabolite p,p'-DDE with Obesity: Integrated Systematic Review and Meta-Analysis. *Environ. Health Perspect.* **2017**, *125*, 096002. [[CrossRef](#)] [[PubMed](#)]
63. Juntarawijit, C.; Juntarawijit, Y. Association between Diabetes and Pesticides: A Case-Control Study among Thai Farmers. *Environ. Health Prev. Med.* **2018**, *23*, 3. [[CrossRef](#)]
64. Sevim, Ç.; Çomaklı, S.; Taghizadehghalehjoughi, A.; Özkaraca, M.; Mesnage, R.; Kovatsi, L.; Burykina, T.I.; Kalogeraki, A.; Antoniou, M.N.; Tsatsakis, A. An Imazamox-Based Herbicide Causes Apoptotic Changes in Rat Liver and Pancreas. *Toxicol. Rep.* **2019**, *6*, 42–50. [[CrossRef](#)] [[PubMed](#)]
65. Buralli, R.J.; Ribeiro, H.; Mauad, T.; Amato-Lourenço, L.F.; Salge, J.M.; Diaz-Quijano, F.A.; Leão, R.S.; Marques, R.C.; Silva, D.S.; Guimarães, J.R.D. Respiratory Condition of Family Farmers Exposed to Pesticides in the State of Rio de Janeiro, Brazil. *Int. J. Environ. Res. Public Health* **2018**, *15*, 1203. [[CrossRef](#)] [[PubMed](#)]
66. Stoleski, S.; Minov, J.; Karadzinska-Bislimovska, J.; Mijakoski, D.; Atanasovska, A.; Bislimovska, D. Asthma and Chronic Obstructive Pulmonary Disease Associated with Occupational Exposure in Dairy Farmers—Importance of Job Exposure Matrices. *Open Access Maced. J. Med. Sci.* **2019**, *7*, 2350. [[CrossRef](#)]
67. Lee, G.H.; Choi, K.C. Adverse Effects of Pesticides on the Functions of Immune System. *Comp. Biochem. Physiol. Part C Toxicol. Pharmacol.* **2020**, *235*, 108789. [[CrossRef](#)]
68. Lerro, C.C.; Koutros, S.; Andreotti, G.; Sandler, D.P.; Lynch, C.F.; Louis, L.M.; Blair, A.; Parks, C.G.; Shrestha, S.; Lubin, J.H.; et al. Cancer Incidence in the Agricultural Health Study after 20 Years of Follow-Up. *Cancer Causes Control.* **2019**, *30*, 311–322. [[CrossRef](#)]
69. Ali, N.; Khan, S.; Khan, M.A.; Waqas, M.; Yao, H. Endocrine Disrupting Pesticides in Soil and Their Health Risk through Ingestion of Vegetables Grown in Pakistan. *Environ. Sci. Pollut. Res.* **2019**, *26*, 8808–8820. [[CrossRef](#)]
70. Barbieri, M.V.; Postigo, C.; Guillem-Argiles, N.; Monllor-Alcaraz, L.S.; Simionato, J.I.; Stella, E.; Barceló, D.; López de Alda, M. Analysis of 52 Pesticides in Fresh Fish Muscle by QuEChERS Extraction Followed by LC-MS/MS Determination. *Sci. Total Environ.* **2019**, *653*, 958–967. [[CrossRef](#)]
71. Köck-Schulmeyer, M.; Postigo, C.; Farré, M.; Barceló, D.; López de Alda, M. Medium to Highly Polar Pesticides in Seawater: Analysis and Fate in Coastal Areas of Catalonia (NE Spain). *Chemosphere* **2019**, *215*, 515–523. [[CrossRef](#)]
72. Kumar, B.; Mishra, M.; Verma, V.K.; Rai, P.; Kumar, S. Organochlorines in Urban Soils from Central India: Probabilistic Health Hazard and Risk Implications to Human Population. *Environ. Geochem. Health* **2018**, *40*, 2465–2480. [[CrossRef](#)]
73. Mahmood, I.; Imadi, S.R.; Shazadi, K.; Gul, A.; Hakeem, K.R. Effects of pesticides on environment. In *Plant, Soil Microbes*; Hakeem, K., Akhtar, M., Abdullah, S., Eds.; Springer: Cham, Switzerland, 2016; pp. 253–269. [[CrossRef](#)]
74. Varjani, S.J.; Joshi, R.R.; Senthil Kumar, P.; Srivastava, V.K.; Kumar, V.; Banerjee, C.; Praveen Kumar, R. Polycyclic aromatic hydrocarbons from petroleum oil industry activities: Effect on human health and their biodegradation. In *Waste Bioremediation*; Varjani, S., Gnansounou, E., Gurunathan, B., Pant, D., Zakaria, Z., Eds.; Springer: Singapore, 2018; pp. 185–199. [[CrossRef](#)]
75. Liu, L.; Bilal, M.; Duan, X.; Iqbal, H.M.N. Mitigation of Environmental Pollution by Genetically Engineered Bacteria—Current Challenges and Future Perspectives. *Sci. Total Environ.* **2019**, *667*, 444–454. [[CrossRef](#)] [[PubMed](#)]
76. Zhang, W.; Jiang, W. UV Treatment Improved the Quality of Postharvest Fruits and Vegetables by Inducing Resistance. *Trends Food Sci. Technol.* **2019**, *92*, 71–80. [[CrossRef](#)]
77. Gong, T.; Li, C.; Bian, B.; Wu, Y.; Dawuda, M.M.; Liao, W. Advances in Application of Small Molecule Compounds for Extending the Shelf Life of Perishable Horticultural Products: A Review. *Sci. Hortic.* **2018**, *230*, 25–34. [[CrossRef](#)]
78. Mbili, N.C.; Opara, U.L.; Lennox, C.L.; Vries, F.A. Citrus and Lemongrass Essential Oils Inhibit Botrytis Cinerea on 'Golden Delicious', 'Pink Lady' and 'Granny Smith' Apples. *J. Plant Dis. Prot.* **2017**, *124*, 499–511. [[CrossRef](#)]
79. Khaliq, G.; Abbas, H.T.; Ali, I.; Waseem, M. Aloe Vera Gel Enriched with Garlic Essential Oil Effectively Controls Anthracnose Disease and Maintains Postharvest Quality of Banana Fruit during Storage. *Hortic. Environ. Biotechnol.* **2019**, *60*, 659–669. [[CrossRef](#)]
80. Majeed, B.; Mohammed, R.; Archives, A.R.-P. Effect of Black Seed Oil and Aloe Vera Gel on Banana Fruit Maturity and Quality. *Plant Arch.* **2019**, *19*, 4459–4462.
81. Peyro, H.; Abbas Mirjalili, S.; Kavooosi, B. Original Contribution Effect of Salicylic Acid and Aloe Vera Gel on Postharvest Quality of Table Grapes (*Vitis vinifera*). *Trakia J. Sci.* **2017**, *15*, 154–159. [[CrossRef](#)]
82. Ali, S.; Khan, A.S.; Nawaz, A.; Anjum, M.A.; Naz, S.; Ejaz, S.; Hussain, S. Aloe Vera Gel Coating Delays Postharvest Browning and Maintains Quality of Harvested Litchi Fruit. *Postharvest Biol. Technol.* **2019**, *157*, 110960. [[CrossRef](#)]
83. Shah, S.; Hashmi, M.S. Chitosan–Aloe Vera Gel Coating Delays Postharvest Decay of Mango Fruit. *Hortic. Environ. Biotechnol.* **2020**, *61*, 279–289. [[CrossRef](#)]
84. Mendy, T.K.; Misran, A.; Mahmud, T.M.M.; Ismail, S.I. Application of Aloe Vera Coating Delays Ripening and Extend the Shelf Life of Papaya Fruit. *Sci. Hortic.* **2019**, *246*, 769–776. [[CrossRef](#)]
85. Khaliq, G.; Ramzan, M.; Baloch, A.H. Effect of Aloe Vera Gel Coating Enriched with Fagonia Indica Plant Extract on Physico-chemical and Antioxidant Activity of Sapodilla Fruit during Postharvest Storage. *Food Chem.* **2019**, *286*, 346–353. [[CrossRef](#)] [[PubMed](#)]

86. Faheem, F.; Liu, Z.W.; Rabail, R.; Haq, I.U.; Gul, M.; Bryła, M.; Roszko, M.; Kieliszek, M.; Din, A.; Aadil, R.M. Uncovering the Industrial Potentials of Lemongrass Essential Oil as a Food Preservative: A Review. *Antioxidants* **2022**, *11*, 720. [CrossRef]
87. Da Silva, E.L.P.; de Carvalho, T.C.; Ayub, R.A.; de Almeida, M.C.M. Nanocellulose Coating Associated with Lemongrass Essential Oil at Postharvest of Blackberry Fruits. *Preprints* **2019**, 2019100131. Available online: <https://doi.org/10.20944/PREPRINTS201910.0131.V1> (accessed on 21 July 2022). [CrossRef]
88. Omoba, O.S.; Onyekwere, U. Postharvest Physicochemical Properties of Cucumber Fruits (*Cucurbit sativus* L.) Treated with Chitosan-Lemon Grass Extracts under Different Storage Durations. *Afr. J. Biotechnol.* **2016**, *15*, 2758–2766. [CrossRef]
89. Hassanein, R.A.; Salem, E.A.; Zahran, A.A. Efficacy of Coupling Gamma Irradiation with Calcium Chloride and Lemongrass Oil in Maintaining Guava Fruit Quality and Inhibiting Fungal Growth during Cold Storage. *Folia Hort.* **2018**, *30*, 67–78. [CrossRef]
90. Siddiqua, M.; Ahmed, S.; Uddin, K.; Tabassum, P.; Sultana, S. Effects of Neem Leaf Extract and Hot Water Treatments on Shelf Life and Quality of Banana. *J. Bangladesh Agric. Univ.* **2018**, *16*, 351–356. [CrossRef]
91. Gupta, N.; Jain, S.K. Storage Behavior of Mango as Affected by Post Harvest Application of Plant Extracts and Storage Conditions. *J. Food Sci. Technol.* **2014**, *51*, 2499–2507. [CrossRef]
92. Freitas, R.V.d.S.; de Souza, P.A.; Senhor, R.F.; Moura, C.F.H.; da Costa, F.B. Post-harvest Storage of Papaya Fruits Coated with Extracts of Leaves and Fruits of Neem. *Rev. Caatinga* **2018**, *31*, 290–296. [CrossRef]
93. Hernández-Valencia, C.G.; Román-Guerrero, A.; Aguilar-Santamaría, Á.; Cira, L.; Shirai, K. Cross-Linking Chitosan into Hydroxypropylmethylcellulose for the Preparation of Neem Oil Coating for Postharvest Storage of Pitaya (*Stenocereus pruinosus*). *Molecules* **2019**, *24*, 219. [CrossRef]
94. Al-Tayyar, N.A.; Youssef, A.M.; Al-Hindi, R.R. Edible Coatings and Antimicrobial Nanoemulsions for Enhancing Shelf Life and Reducing Foodborne Pathogens of Fruits and Vegetables: A Review. *Sustain. Mater. Technol.* **2020**, *26*, e00215. [CrossRef]
95. Yousuf, B.; Qadri, O.S.; Srivastava, A.K. Recent Developments in Shelf-Life Extension of Fresh-Cut Fruits and Vegetables by Application of Different Edible Coatings: A Review. *LWT* **2018**, *89*, 198–209. [CrossRef]
96. Anjum, M.A.; Akram, H.; Zaidi, M.; Ali, S. Effect of Gum Arabic and Aloe Vera Gel Based Edible Coatings in Combination with Plant Extracts on Postharvest Quality and Storability of ‘Gola’ Guava Fruits. *Sci. Hort.* **2020**, *271*, 109506. [CrossRef]
97. Ali, J.; Pandey, S.; Singh, V.; Joshi, P. Effect of Coating of Aloe Vera Gel on Shelf Life of Grapes. *Curr. Res. Nutr. Food Sci. J.* **2016**, *4*, 58–68. [CrossRef]
98. Danish, P.; Ali, Q.; Hafeez, M.; Malik, A. Antifungal and Antibacterial Activity of Aloe Vera Plant Extract. *Biol. Clin. Sci. Res. J.* **2020**. Available online: <http://bcsrcj.com/ojs/index.php/bcsrcj/article/view/4> (accessed on 21 July 2022).
99. Jagana, D.; Hegde, Y.; Lella, R.; Hegde, Y.R. Bioefficacy of Essential Oils and Plant Oils for the Management of Banana Anthracnose—A Major Post-Harvest Disease Bioefficacy of Essential Oils and Plant Oils for the Management of Banana Anthracnose—A Major Post-Harvest Disease. *Int. J. Curr. Microbiol. App. Sci.* **2018**, *7*, 2359–2365. [CrossRef]
100. Kamsu, N.P.; Tchinda, S.E.; Tchameni, N.S.; Jazet, D.P.M.; Madjouko, M.A.; Youassi Youassi, O.; Sameza, M.L.; Tchoumboungang, F.; Menut, C. Antifungal Activities of Essential Oils of Cinnamon (*Cinnamomum zeylanicum*) and Lemongrass (*Cymbopogon citratus*) on Crown Rot Pathogens of Banana. *Indian Phytopathol.* **2019**, *72*, 131–137. [CrossRef]
101. Tovar, C.D.G.; Delgado-Ospina, J.; Porras, D.P.N.; Peralta-Ruiz, Y.; Cordero, A.P.; Castro, J.I.; Valencia, M.N.C.; Mina, J.H.; López, C.C. Colletotrichum Gloesporioides Inhibition In Situ by Chitosan-Ruta Graveolens Essential Oil Coatings: Effect on Microbiological, Physicochemical, and Organoleptic Properties of Guava (*Psidium guajava* L.) during Room Temperature Storage. *Biomolecules* **2019**, *9*, 399. [CrossRef]
102. Mditshwa, A.; Magwaza, L.S.; Tesfay, S.Z.; Opara, U.L. Postharvest Factors Affecting Vitamin C Content of Citrus Fruits: A Review. *Sci. Hort.* **2017**, *218*, 95–104. [CrossRef]
103. Da Silva, E.L.P.; de Carvalho, T.C.; Ayub, R.A.; de Almeida, M.C.M. Blackberry Extend Shelf Life by Nanocellulose and Vegetable Oil Coating. *Horticult. Int. J.* **2020**, *4*, 54–60. [CrossRef]
104. Pinto, L.; Cefola, M.; Bonifacio, M.A.; Cometa, S.; Bocchino, C.; Pace, B.; De Giglio, E.; Palumbo, M.; Sada, A.; Logrieco, A.F.; et al. Effect of Red Thyme Oil (*Thymus vulgaris* L.) Vapours on Fungal Decay, Quality Parameters and Shelf-Life of Oranges during Cold Storage. *Food Chem.* **2021**, *336*, 127590. [CrossRef]
105. Sarmin, R.; Khan, S.; Fatema, K. Effect of Neem Leaf and Banana Pulp Extracts on Shelf Life and Quality of Mango (*Mangifera indica* L.). *J. Bangladesh Agric. Univ.* **2018**, *16*, 343–350. [CrossRef]
106. Ndale Zakawa, A. Antifungal Effect of Neem (*Azadirachta indica*) Leaf Extracts on Mango Fruit Post-Harvest Rot Agents in Yola, Adamawa State. *J. Pharmacogn. Phytochem.* **2018**, *7*, 23–26.
107. Zewdie, B.; Shonte, T.T.; Woldetsadik, K. Shelf Life and Quality of Tomato (*Lycopersicon esculentum* Mill.) Fruits as Affected by Neem Leaf Extract Dipping and Beeswax Coating. *Int. J. Food Prop.* **2022**, *25*, 570–592. [CrossRef]
108. Bobo, G.; Arroqui, C.; Virseda, P. Natural Plant Extracts as Inhibitors of Potato Polyphenol Oxidase: The Green Tea Case Study. *LWT* **2022**, *153*, 112467. [CrossRef]
109. Gull, A.; Bhat, N.; Wani, S.M.; Masoodi, F.A.; Amin, T.; Ganai, S.A. Shelf Life Extension of Apricot Fruit by Application of Nanochitosan Emulsion Coatings Containing Pomegranate Peel Extract. *Food Chem.* **2021**, *349*, 129149. [CrossRef]
110. Parsa, Z.; Roozbehi, S.; HosseiniFarahi, M.; Radi, M.; Amiri, S. Integration of Pomegranate Peel Extract (PPE) with Calcium Sulphate (CaSO<sub>4</sub>): A Friendly Treatment for Extending Shelf-Life and Maintaining Postharvest Quality of Sweet Cherry Fruit. *J. Food Process. Preserv.* **2021**, *45*, e15089. [CrossRef]

111. Saleh, I.; Abu-Dieyeh, M. Novel Prosopis Juliflora Leaf Ethanolic Extract Coating for Extending Postharvest Shelf-Life of Strawberries. *Food Control* **2022**, *133 Pt B*, 108641. [[CrossRef](#)]
112. Gustavo, W.; Peixoto, C.; Ribeiro, P.; Regina, N.; Benta, M.; Rodrigues, C.; Gonçalves, C.; Peruzzo, J.; Paula, A.; Veeck, D.L.; et al. Biocatalysis and Agricultural Biotechnology Bioactive and PH-Sensitive Films Based on Carboxymethyl Cellulose and Blackberry (*Morus nigra* L.) Anthocyanin-Rich Extract: A Perspective Coating Material to Improve the Shelf Life of Cherry Tomato (*Solanum lycopersicum* L. var. *cerasiforme*). *Biocatal. Agric. Biotechnol.* **2021**, *33*, 101989. [[CrossRef](#)]
113. Sarkhosh, A.; Schaffer, B.; Vargas, A.I.; Palmateer, A.J.; Lopez, P.; Soleymani, A.; Farzaneh, M. Antifungal Activity of Five Plant-Extracted Essential Oils against Anthracnose in Papaya Fruit. *Biol. Agric. Hortic.* **2018**, *34*, 18–26. [[CrossRef](#)]
114. Hosseini, H.; Jafari, S.M. Introducing Nano/Microencapsulated Bioactive Ingredients for Extending the Shelf-Life of Food Products. *Adv. Colloid Interface Sci.* **2020**, *282*, 102210. [[CrossRef](#)]
115. Nazarzadeh Zare, E.; Makvandi, P.; Tay, F.R. Recent Progress in the Industrial and Biomedical Applications of Tragacanth Gum: A Review. *Carbohydr. Polym.* **2019**, *212*, 450–467. [[CrossRef](#)]
116. Nyamath, S.; Karthikeyan, B.; Syed Nyamath, C. In Vitro Antifungal Activity of Lemongrass (*Cymbopogon citratus*) Leaf Extracts. *J. Pharmacogn. Phytochem.* **2018**, *7*, 1148–1151.
117. Tesfay, S.Z.; Magwaza, L.S. Evaluating the Efficacy of Moringa Leaf Extract, Chitosan and Carboxymethyl Cellulose as Edible Coatings for Enhancing Quality and Extending Postharvest Life of Avocado (*Persea americana* Mill.) Fruit. *Food Packag. Shelf Life* **2017**, *11*, 40–48. [[CrossRef](#)]
118. Koltz, E.A.; dos Santos, I.; Dallemole-Giaretta, R.; Pazolini, K.; Leite, C.D.; Steilmann, P. Combining Brassica Sachets and Extracts with Thermotherapy against Postharvest Green Mold of Orange. *Sci. Hortic.* **2020**, *268*, 109389. [[CrossRef](#)]
119. Bordoh, P.K.; Ali, A.; Dickinson, M.; Siddiqui, Y. Antimicrobial Effect of Rhizome and Medicinal Herb Extract in Controlling Postharvest Anthracnose of Dragon Fruit and Their Possible Phytotoxicity. *Sci. Hortic.* **2020**, *265*, 109249. [[CrossRef](#)]
120. Cui, K.; Shu, C.; Zhao, H.; Fan, X.; Cao, J.; Jiang, W. Preharvest Chitosan Oligochitosan and Salicylic Acid Treatments Enhance Phenol Metabolism and Maintain the Postharvest Quality of Apricots (*Prunus armeniaca* L.). *Sci. Hortic.* **2020**, *267*, 109334. [[CrossRef](#)]
121. Bouarab-Chibane, L.; Ouled-Bouhedda, B.; Leonard, L.; Gemelas, L.; Bouajila, J.; Ferhout, H.; Cottaz, A.; Joly, C.; Degraeve, P.; Oulahal, N. Preservation of Fresh Ground Beef Patties Using Plant Extracts Combined with a Modified Atmosphere Packaging. *Eur. Food Res. Technol.* **2017**, *243*, 1997–2009. [[CrossRef](#)]
122. Oulahal, N.; Degraeve, P. Phenolic-Rich Plant Extracts with Antimicrobial Activity: An Alternative to Food Preservatives and Biocides? *Front. Microbiol.* **2022**, *12*, 3906. [[CrossRef](#)] [[PubMed](#)]
123. Swer, T.L.; Chauhan, K.; Mukhim, C.; Bashir, K.; Kumar, A. Application of Anthocyanins Extracted from Sohiong (*Prunus nepalensis* L.) in Food Processing. *LWT* **2019**, *114*, 108360. [[CrossRef](#)]