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Review

Use of Non-Chlorine Sanitizers in Improving Quality and Safety of Marketed Fresh Salad Vegetables

Sharmin Zaman [1], Ashfaq Aziz [1], Md. Abubakkar Siddique [2], Md. Abdul Khaleque [3] and Md. Latiful Bari [1,*]

[1] Center for Advanced Research in Sciences, University of Dhaka, Dhaka 1000, Bangladesh
[2] WAFFEN Research Laboratory Limited, Blue Moon Gram Tower (7th Floor), 167/24, Matikata, ECB Chattar, Kalshi, Mirpur, Dhaka 1206, Bangladesh
[3] Department of Biochemistry and Microbiology, North South University, Bashundhara, Dhaka 1229, Bangladesh
* Correspondence: latiful@du.ac.bd

Abstract: The safety of vegetable food is compromised by various factors, including the inefficient or excessive use of sanitizers. Instances of individuals falling ill after consuming raw vegetables have been reported, with outbreaks of diseases caused by pathogens on fresh vegetables becoming increasingly prevalent globally, attracting significant media coverage and impacting the economic viability of vegetable cultivation. Measures to enhance food safety in postharvest horticultural produce involve controlling microbial proliferation and minimizing cross-contamination. Sanitizers were utilized in the food safety arsenal for a variety of purposes, including pathogen elimination and microbe reduction, hand, tool, and vegetable contact surface cleaning, and produce shelf-life extension. Choosing an appropriate sanitizer for all vegetables is difficult due to a lack of knowledge on which sanitizers are ideal for the many types of vegetables grown on farms under different environmental circumstances. Although chlorine-based sanitizers, such as sodium or calcium hypochlorite, have been widely used for the past 50 years, recent research has revealed that chlorine reacts with an organic compound in fresh vegetables to produce trihalomethane, a carcinogen precursor, and as a result, many countries have prohibited the use of chlorine in all foods. As a result, horticulture research groups worldwide are exploring non-chlorine, ecologically friendly sanitizers for the vegetable industry. They also want to understand more about the present procedures in the vegetable business for employing alternative sanitizers, as well as the efficacy and potential dangers to the food safety of fresh salad vegetables. This review paper presents detailed information on non-chlorine sanitizers, such as their efficacy, benefits, drawbacks, regulatory requirements, and the need for additional research to lower the risk of marketed salad vegetable food safety.

Keywords: non-chlorine sanitizer; food safety; common fresh salad vegetables

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1. Introduction

Vegetables are becoming a more essential "healthy" group than animal proteins, complex carbohydrates, or sweeter alternatives like fruits in today's diets, as consumers demand safer, fresher, and healthier options [1–3]. Fresh vegetables, including cucumber, tomato, carrot, capsicum, lettuce, green chili, and onion, are frequently used as salad items in Asian countries and are an essential part of a healthy diet. The demand for ready-to-eat fresh produce also means that cutting, peeling, and dicing vegetables is an increasingly common practice, significantly raising food safety risks. Bacteria (such as *Aeromonas* spp., *Bacillus cereus*, *Clostridium botulinum*, *Clostridium perfringens*, *E. coli* (pathogenic and non-pathogenic), *L. monocytogenes*, *Pseudomonas* spp., *Salmonella* spp., *Shigella* spp., *S. aureus*, and *Yersinia enterocolitica*), viruses (such as Hepatitis A, Rotavirus and Norovirus), and parasites (such as *Cryptosporidium parvum*, *Cyclospora cayetanensis*, *Giardia lamblia*, and *Toxoplasma gondii*) are the food safety concern microorganisms. Table 1 provides a list of the microorganisms responsible and the specific vegetables that contributed to foodborne outbreaks.

Table 1. Selected vegetable pathogens linked with outbreaks.

Bacteria	Selected Vegetables	References
Toxin producing Bacteria		
Clostridium botulinum	Carrots	[4]
Escherichia coli	Lettuce, tomato	[5,6]
Staphylococcus aureus	Lettuce, tomato, and carrot	[7–9]
Non-toxin producing Bacteria		
Listeria monocytogenes	Lettuce, tomato	[10,11]
Salmonella spp.	Lettuce, tomato	[12,13]
Shigella spp.	Lettuce, salad vegetables	[14]
Yersinia enterocolitica	Carrots, cucumber, lettuce, and tomatoes	[15–17]
Viruses		
Hepatitis A and Norovirus	Lettuce	[18,19]
Protozoa		
Cryptosporidium spp. and *Cyclospora* spp.	Lettuce	[20,21]

Plant pathogenic fungi are mainly responsible for the spoilage of vegetables, known as quality deterioration. The initial microbial loads and diversity of microorganisms present on fresh vegetables at harvest vary depending on factors such as horticultural practices, employee health and hygiene, field or farm settings, farm management regimens, and so on [22,23]. In addition, not all microorganisms are capable of proliferating on produce commodities. Several microbial species, however, can break the protective barriers plants possess, grow, and cause spoilage of these products, while others can enter the plant tissue only through wounds, but once the protective cover has been compromised, the chances of spoilage increase exponentially [24]. Common spoilage bacteria including *Aeromonas* spp., *Pectobacterium* spp., *Xanthomonas* spp., *Pseudomonas* spp., and *Erwinia* spp. are mainly responsible for bacterial soft rot, while *Bacillus* spp. and lactic acid bacteria cause the spoilage of vegetables, known as quality deterioration. Common fungi species, including *Rhizopus stolonifer*, *Fusarium oxysporum*, *Aspergillus niger*, *Fusarim solani*, and *Geotrichum candidum*, were found to be associated with the spoilage of horticultural crops [25,26]. Table 2 summarizes the microorganisms causing postharvest deterioration of various fresh vegetables.

Table 2. Summary of microorganisms causing postharvest spoilage of selected fresh produce.

Bacteria/Fungi	Type of Spoilage	Selected Vegetables	References
Aeromonas and Pectobacterium spp.	bacterial soft rot	Lettuce	[27]
Lactic acid bacteria	spoilage	Tomato	[28]
Xanthomonas	leaf spot and bacterial spot on tomato	Lettuce and Tomato	[29]
Pseudomonas	bacterial spot	Carrot, Lettuce, and Tomato	[29]
Erwinia	soft rot	Carrot, Cucumber, Lettuce, and Onion	[29]
Bacillus coagulans	spoilage	Cucumber, Onion, and Tomato	[29]

Table 2. *Cont.*

Bacteria/Fungi	Type of Spoilage	Selected Vegetables	References
Thielaviopsis basicola	black root rot	Carrot	[30]
Pythium	cottony rot	Cucumber	[29]
Phytophthora	Buckeye rot	Tomato	[31]
Penicillium (blue mold) and Rhizopus	spoilage	Cucumber and Tomato	[29]
Aspergillus niger	black rot	Onion and Tomato	[32]
Sclerotinia	white rot, white mold	Carrot, Lettuce, and Tomato	[24]
Geotrichum	sour rot	Carrot, Lettuce, Onion, and Tomato	[33]
Collectotrichum	Anthracnose	Capsicum, Cucumber, Onion, and Tomato	[34]
Rhizopus spp.	storage rot, rhizopus rot	Capsicum, Carrot, Cucumber, and Tomato	[35]
Botrytis spp.	neck rot, grey mold	Carrot, Cucumber, Lettuce, Onion, and Tomato	[29]
Fusarium and Alternaria spp.	soft rot, dry rot, and black rot	Capsicum, Carrot, Cucumber, Onion, and Tomato,	[27]

All of these vegetables have the potential to pick up pathogenic microorganisms while being harvested on the field, handled afterward, processed and packaged in the pack house, or transported and distributed to stores. The agroecology of the geographical locations, genetic diversity, agronomic practices, and environmental responses in different farm production stages all influence the level of microbial contamination. Following the postharvest process, human activity and the environmental responses of the vegetable-packing plants can also increase the risk of contamination. The overwhelming majority of published studies stated that contamination occurs primarily prior to harvesting, either from animals, domestic or wild; through contaminated manure, sewage, irrigation water, wastewater from livestock operations; during harvesting, transport, processing, distribution, pack house, and marketing; or even at home [36–39]. Vegetable food safety risks in connection to agroecology during farm production and the environment of vegetable-packaging facilities during postharvest operations can be significant, and this field of study is just beginning. As mentioned in the literature, vegetables can also become infected at the retail or consumer levels, and this can happen through direct contamination, contact with contaminated soil or water, symptomatic and asymptomatic employees, or cross-contamination with other foods [40]. This risk, however, is completely determined by regional food safety culture, which is also a new area of study. Figure 1 depicts the typical annual average microbiological quality and safety indicator microorganisms discovered in different salad vegetables in Bangladesh from 2010 to 2022, where almost all the parameters are above the acceptable limit set by the regulatory agencies.

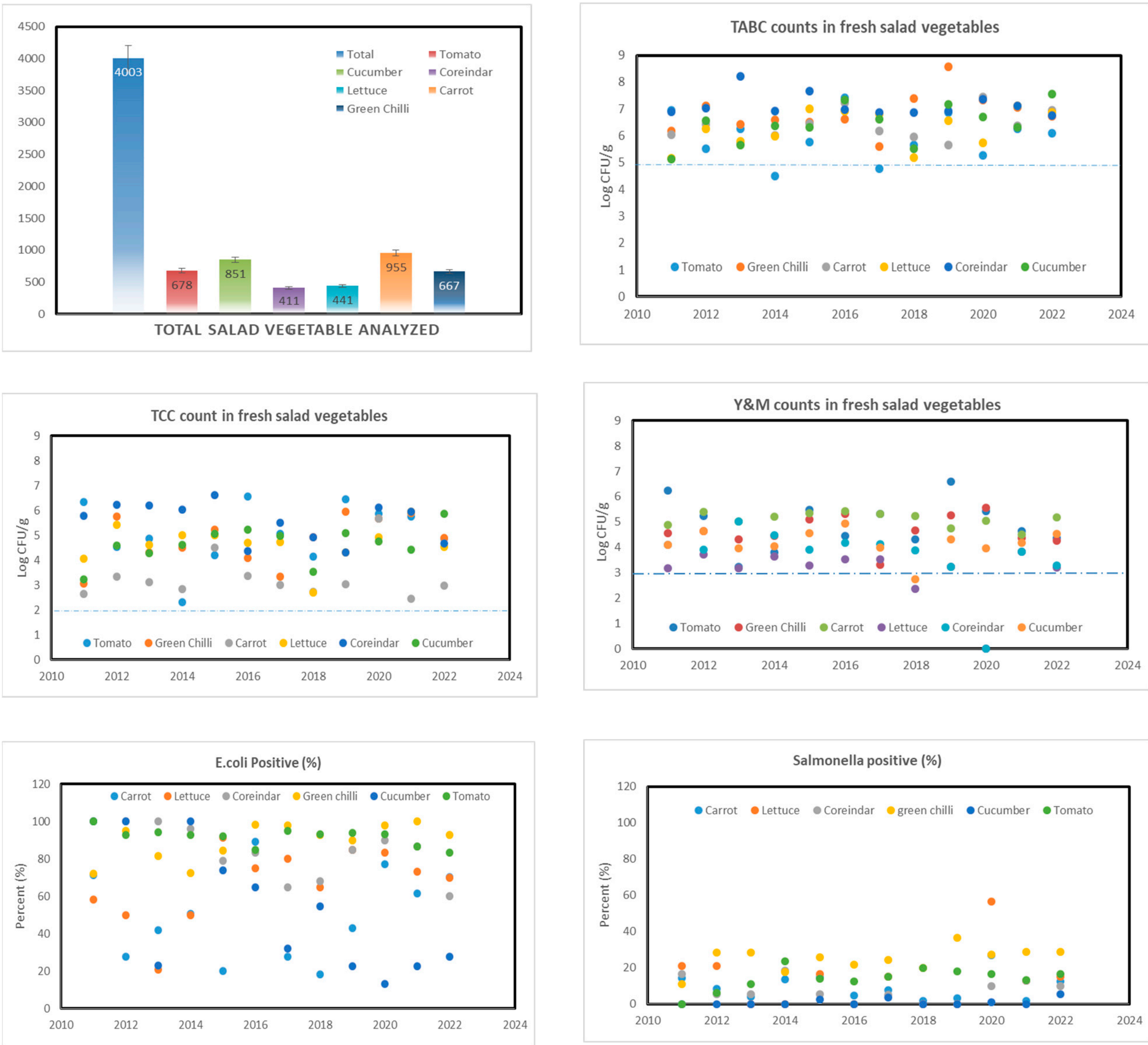

Figure 1. Indicators of microbiological quality (total aerobic bacteria, total coliform bacteria, total yeast, and mold) and safety (*E. coli* and *Salmonella*) were distributed on an annual basis in salad vegetables such as tomato, cucumber, carrot, coriander leaf, green chili, and lettuce in Bangladesh between 2011 and 2022 [41].

2. Use of Sanitizers

The most common reasons to use sanitizer are: (1) to eliminate any bacteria or pathogens and lower microbial load; (2) to control microbiological hazards from human sources; (3) to maintain a safe environment and control product cross-contamination; (4) to reduce fungi's ability to propagate; (5) to disinfect and/or clean the processing facility, machinery, and any surfaces that come into contact with the vegetable crop; (6) to make sterile water; (7) to sterilize water-holding vessels; (8) to maintain the product's cleanliness; and (9) to increase shelf life [42].

Although various microbial agents are available for sanitizing fresh produce, their efficacies differ, and none can eliminate pathogens without compromising sensory quality. Recent research has also demonstrated that chlorine is ineffective at reducing pathogens, and the creation of chlorine byproducts harms human health [43]. As a consequence, there is considerable interest in developing a chlorine substitute that is both safer and better for the environment. On the other hand, various non-chlorine sanitizers including, calcined calcium, hydrogen peroxide, ozone, peroxyacetic acid, organic acid, natural antimicrobial agents, or combinations of these and other physical sanitization techniques have been seen in the literature for washing fresh salad vegetables to improve the quality and safety of these vegetables; however, it is vital to remember that the efficiency of any sanitizer, chlorine or non-chlorine, depends on factors such as concentration, contact time, and application method. Proper handling and sanitation practices are crucial regardless of the type of sanitizer used to ensure the safety and quality of fresh salad vegetables. Additionally, regulatory guidelines and specific industry requirements should be considered when selecting and implementing sanitization methods. The disadvantages and advantages of chlorine-based sanitizers and non-chlorine sanitizers are summarized in Table 3.

Table 3. The disadvantages and advantages of chlorine-based sanitizers and non-chlorine sanitizers.

Factors	Chlorine-Based Sanitizers	Non-Chlorine Sanitizers
Reduced Chemical Residue	Can leave behind chemical residues that may affect the taste and safety of vegetables	Can effectively sanitize vegetables without leaving harmful residues
Gentler on Produce	Can sometimes be harsh on delicate salad vegetables, potentially causing discoloration or off-flavors	Often gentler and less likely to affect the appearance or taste of the vegetables
Effective Pathogen Reduction	Can be effective in pathogen reduction but the creation of chlorine byproducts harms human health	Can effectively reduce pathogens and no known byproducts which harm human health are produced
Organic Compliance	Does not adhere to organic standards	Align more closely with organic certification requirements
Versatility	May not be suitable for certain sensitive vegetables	Often be used across a wider range of vegetables without adverse effects
Reduced Environmental Impact	Can have environmental implications, including the formation of harmful disinfection byproducts	No environmental implications or impact and no formation of harmful byproducts
Consumer Preferences	May not be preferred by some consumers because they cause harm to the environment	May be preferred due to perceived health and environmental benefits

Generally, the ideal sanitizing agent should possess two key qualities: an adequate level of antimicrobial activity and little to no impact on the product's sensory quality. Consumer demands for safe and ecologically friendly products would increasingly influence sanitizer selection for both domestic and international use. There is a lack of information on suitable alternatives, more environmentally friendly sanitizers, their efficacy on various products, and their market acceptance. The US Environmental Protection Agency (EPA) has registered and authorized nearly 4000 antimicrobial sanitizers, including 275 distinct active components [44]. Choosing the best sanitizer for specific vegetables (cucumber, tomato, carrot, capsicum, lettuce, green chili, and onion) might be challenging, given the lengthy list. The most commonly used sanitizers in the food business are chlorine-based, which include sodium or calcium hypochlorite, acidified chlorite, electrolyzed water, and others; they have been tested on a variety of fresh produce and are effective against a wide range of pathogens [45]. However, chlorine can interact with organic matter in the natural environment to produce halogenated byproducts like trihalomethanes or haloacetic acids [46]. Because these byproducts are carcinogenic and unfriendly to the environment, using chlorine to wash fresh vegetables has been prohibited in countries such as Belgium, Switzerland, and the Netherlands for safety reasons [47]. As a result, Table 4 includes a number of substitute sanitizers proven to improve the safety and quality of salad vegetables, such as calcinated calcium, aqueous chlorine dioxide (ClO_2), ozone, hydrogen peroxide, peroxyacetic acid, organic acid, and plant bioactive compounds or essential oils. Table 4 describes each non-chlorine sanitizer, their dose level, advantages, and disadvantages.

Table 4. List of various applicable non-chlorine sanitizers for washing fresh salad vegetables.

Sanitizer	Allowable Levels	Advantages	Disadvantages	Rinse Step	Additional Comments	References
Calcinated calcium (CCa)	Use 1 g powder/10 L water (giving a concentration of 0.01% and pH about 11) and 40 s wash.	Calcinated calcium (CCa) is safe and eco-friendly; produced from marine waste (scallop shells).	If not dissolved properly, may contribute to residues on the vegetable surface. Can be affected by organic load in wash water.	Yes	Effective at lower dose, high pH, and less contact time. Available and cheap.	[48,49]
Hydrogen peroxide (H_2O_2)	Typical concentration used: (0.04–2%). Environmentally friendly. Declared GRAS by FDA.	Breaks down easily, no harmful by-products. Higher temperatures could produce better reduction.	Higher concentrations can cause browning or bleaching in certain products and can be corrosive and irritating. Unstable and degrades fast.	No	Commercially available at 31–70% but 30–50% is most common. Dilute (3%) solutions are available to consumers.	[50,51]
Ozone (O_3)	No regulatory limit but typically used at 2–10 ppm for up to 5 min. Activity reduced in presence of organic load.	Declared GRAS by FDA. Environmentally friendly. Effective at low concentrations. No harmful end products.	Has to be generated on-site; unstable and highly reactive. Corrosive to equipment. OSHA requirements on employee exposure.	No	Solubility in water increases at lower temperatures and pH. Does not work as well at higher pH.	[52–56]
Organic acids (acetic acid, citric acid, lactic acid, tartaric acid, oxalic acid, ascorbic acid, and phytic acid)	1% oxalic acid, 0.03% phytic acid, 0.5% CA, 0.5% lactic for 2 min or 2% acetic acid for 15 min.	Organic acids have been used as sanitizers for fresh produce. The FDA recognizes organic acids as GRAS.	Their usefulness against microorganisms is generally low and requires high concentrations for long periods. Sensory quality might also be affected with 5–15 min treatment.	No	Effective at higher conc., depends on water quality and costly. Antimicrobial efficacy is dependent on the microorganism strain and acid type.	[57–59]
Aqueous chlorine dioxide (ClO_2)	ClO_2 5 mg/L, 60 s overhead spray and brush roller system at 25 °C.	Easy to handle; inexpensive. It can be used in the form of a spray, or by immersion or washing. Concentration and contact can be maintained. Easy to adopt in industrial washing lines.	Produce surface properties can affect ClO_2 accessibility to microbes. Residual moisture after the water rinsing can promote microbial growth.	Yes	Not suitable for dried foods. Relatively less effect on microbial Internalization.	[60,61]
Peroxyacetic acid	Strong oxidizing agent. Use 80 ppm–150 ppm; 2 min on fruits and vegetables. Can work well in cooler temperatures.	Environmentally friendly and less corrosive to equipment. Works at a wide range of pH values and temperatures. Effective against biofilms. Not as sensitive to organic load as chlorine.	Costs more than chlorine. Vinegar odor. Loses its effectiveness in the presence of metals (copper). High concentrations damage produce and can shorten shelf life.	No	Store in a well-ventilated area. Concentrated peroxyacetic acid is a safety hazard.	[62–66]
Plant extracts (bioactive compounds)	Grape stem extract, 2.5% solution; 2 min, and dried for 30 min could reduce pathogens by 2.0–4.0 log CFU/g in lettuce. Oregano aqueous extract for 2 min. Green tea extract 60% GTE for 5 min. Essential oil (Cypriot oregano), 0.1% for 10 min.	The antibacterial activity could be due to the damage of cytoplasmic membranes, inhibition of synthesis of nucleic acids, cell wall components, and cell membranes [67,68].	Fewer effects than chemical sanitizers and non-economic efficiency. Unpleasant aroma. Longer durations.	No	Store in dark place. Since sensitive to light, volatile nature. Higher concentration (0.5%) results in softer fruits.	[69–72]

GRAS = generally recognized as safe; GTE = green tea extract.

2.1. Calcinated Calcium (Green Agrowash®)

Calcinated calcium is a pyrolysis product of waste shell aggregate, which is baked into a fine, odorless, natural, environmentally beneficial, and biodegradable powder. Japan's Specifications and Standards for Food Additives (JSFA) has approved using this shell powder with microparticles in food. This powder is sparingly soluble in water and possesses antibacterial and antifungal activities, which has proven effective in killing bacteria and fungi and removing contaminants from the fruit and vegetable surfaces [73–75]. One gram of powder in 10 L tap water, or (0.01% solution), is recommended for a 40–60 s wash. Followed by a clean water wash, this was able to eliminate pathogens and remove other contaminants from the surface of the vegetables. However, using more than the suggested concentration can leave a white stain on stainless steel or glass surfaces. Since calcinated calcium is made from natural ingredients, it is readily accessible, inexpensive, does not harm the environment, and is not toxic to humans or animals.

2.2. Hydrogen Peroxide

Hydrogen peroxide, commonly known as hydrogen dioxide, can be used to sterilize fruits and vegetables as a liquid or gas. It is considered "generally recognized as safe" or GRAS by the FDA and EPA and is environmentally friendly because it breaks down to oxygen and water. The organic load in the wash water has an impact on it, but pH has no effect. Fresh vegetables can be sanitized with hydrogen peroxide at concentrations no more than 59 ppm, according to FDA approval. The usage of hydrogen peroxide in conjunction with acetic acid (PAA) has increased recently, as opposed to using it alone. Hydrogen peroxide causes cells to die by altering osmotic pressure, leading to the loss of cell wall integrity. This compound is cheap, easy to prepare, fast acting for bacteria, and can kill spores. Hydrogen peroxide must be used cautiously because it is unstable in water, highly allergenic, and loses potency if not stored properly.

2.3. Ozone

Ozone is also thought to have high antimicrobial activity and has a high level of reactivity and penetrability [76]. Ozone generation/production has lower operating costs, and it is GRAS. It was investigated how the microbial population and fresh-cut produce's qualitative features were affected by ozonated water at varying concentrations and contact times [77]. Ozone breaks down into non-toxic compounds and does not produce any dangerous disinfection byproducts. Aqueous ozone is less effective than gaseous ozone against both pathogenic and non-pathogenic bacteria. However, gaseous ozone may be harmful, poisonous, and reactive in this state [78–80].

2.4. Organic Acids

Fresh fruit has been sanitized using organic acids like citric acid, acetic acid, and lactic acid as well as combinations with phosphoric acid and sulfuric acid. These substances cannot stain or emit odors and are not corrosive to stainless steel, making them more natural ingredients in food. On the negative side, yeasts, fungi, Gram-positive bacteria, and others are not destroyed by organic acids. Although organic acids are deemed GRAS by the FDA, their effectiveness against microorganisms is typically low and they are needed at high concentrations for extended periods of time. Fresh and freshly cut vegetables have been sanitized using organic acids and acid compound sanitizers. In order to maintain the physical and chemical properties of many fresh-cut products, and to stop microbial development, organic acids are crucial sanitizers. According to [81], decontaminating leaves of some particular vegetables with 5% citric acid resulted in a noticeably lower microbial count than washing them with water. The ideal form of organic acid had no negative effects on flavor or taste, and it had no negative effects on the ecosystem. Fresh-cut fruit can have their shelf life extended by citric acid because it prevents the food quality from deteriorating and the spread of disease. However, using these acids at greater concentrations may lead to a quality loss in some freshly cut leafy vegetables due to off-odors and texture damage.

It has also been investigated how the order of citric acid and ethanol treatment affects the quality and microbial reduction in organic vegetables. As a result, an organic acid-based disinfectant has been developed using a combination of technologies in place of chlorine.

2.5. Chlorine Dioxide

Fresh fruit can be effectively protected from bacterial, fungal, and viral contamination by using the oxidizing gas ClO_2 [82,83]. ClO_2 is effective across a wide pH range (pH 3–8) and does not create any toxic byproducts or change the nutritive or olfactory qualities of food products. However, using ClO_2 to wash fresh products in gaseous and aqueous forms has benefits and drawbacks, which are listed in Table 5.

Table 5. Chlorine dioxide (ClO_2) application in the aqueous and gaseous form: advantages and disadvantages.

Aqueous ClO_2 [45]	
Advantages	**Disadvantages**
Easy to handle, inexpensive	Produce surface properties can affect ClO_2 accessibility to microbes
It can be used in the form of a spray, by immersion or washing	Cross-contamination of wash water
Concentration and contact can be maintained	Water rinsing is required after the treatment
Easy to adopt in industrial washing lines	Residual moisture after the water rinsing can promote microbial growth
	Not suitable for dried foods
	Relatively less effective on microbial internalization
Gaseous ClO_2 [77]	
Advantages	**Disadvantages**
Higher antimicrobial activity	Needs onsite generation
It can be applied as a batch treatment or a continuous treatment	Needs technical knowledge
High accessibility to microbes, irrespective of surface barriers	Laborious to perform and expensive
No water rinsing is required after the treatment	Explosive at higher concentrations
It can impact microbial internalization	Challenging to maintain concentration and contact time
No issue of cross-contamination of wash water	Challenging to implement at the industry scale

2.6. Natural Plant Extracts

Natural goods are increasingly being looked into as alternatives to conventional sanitizing agents in the washing processes for fresh produce. Essential oils (EOs) and hydrosols from aromatic plants are examples of natural plant extracts that are generally accepted as safe (GRAS) for use in the food industry and are also covered by EC Regulation No. 1334/2008 on flavorings and certain food ingredients with flavoring properties for use in and on foods [84,85]. Numerous EOs and other natural extracts, such as sage, Greek oregano, eucalyptus, and rosemary, have been used to preserve fresh produce and barely processed vegetables [86–89]. Furthermore, no variations in lowering *E. coli* O157: H7 and total coliforms in lettuce and spinach were discovered after washing with water and tannin solutions [90]. Washing spinach and lettuce samples in aqueous oregano extract for two minutes reduced *E. coli* O157:H7 counts by 2.1 log CFU g^{-1} and 3.7–4.0 log CFU g^{-1}, respectively, when coupled with Citrox® (a product containing citric acid and phenolic compounds) [91]. These findings suggested that plant extracts can successfully decrease the pathogenic load in fresh vegetables. Edible coatings with natural antimicrobial agents are becoming more popular as possible treatments to lessen the adverse effects of processing fresh vegetables. However, using natural edible coatings for freshly cut vegetables has not attracted attention, and vegetable businesses have yet to wash or preserve fresh-cut vegetables using a natural antimicrobial agent due to fewer side effects than chemical sanitizers and non-economic efficiency. Plant extracts should also be kept in the dark because they are typically volatile and light-sensitive. Vegetables may become softer when plant extracts are used in greater concentrations (0.5%). The washing of fresh organic produce offered at a higher price can be achieved with natural detergents. The need for natural food preservation techniques, such as using natural antimicrobials and their combination with other obstacles, without adverse effects on the consumer or the environment, has been brought on by consumers' increasing demand for fresh and freshly cut produce [92]. Essential oils are natural antimicrobial agents; however, it is practically difficult to use these oils because of their hydrophobic, volatile, and unstable nature [93].

2.7. Green Tea Extract

Green tea extract (GTE; 60%) was shown by [94] to exhibit a rise in antiviral activity with increasing pH. The cytoplasmic membrane damage, nucleic acid synthesis suppression, cell wall component inhibition, and cell membrane damage could contribute to the antibacterial activity [95,96]. Temperature, concentration, and contact time all impacted GTE's reaction. For lettuce and spinach, using 60% GTE also successfully lowered the bacterial count by 1.5 logs after 30 min of exposure. A non-economic and occasionally greater dosage of GTE may result in an unpleasant odor and soften the vegetables because it requires longer times, less effectiveness, and a higher concentration than chemical sanitizers (Table 6).

Table 6. Efficacy of non-chlorine-based sanitizers in reducing bacterial pathogens from fresh salad vegetables' surfaces.

Vegetables	Non-Chlorine Sanitizers (Conc. and Contact Time)	Microorganisms	Maximum Reduction (log CFU/g)	Complete Reduction/Number of Samples	References
Lettuce	Peracetic acid (PAA) (100 mg/L; 5 min at 65 rpm)	*Escherichia coli* O157:H7,	2.2	0/6	[89]
		Salmonella typhimurium DT104	6.8	6/6	
		Listeria monocytogenes,	2.4	0/6	
	Lactic acid (2%; 5 min at 65 rpm)	*Escherichia coli* O157:H7,	1.7	0/6	
		Listeria monocytogenes,	1.7	0/6	
	Calcinated calcium (0.01% for 40–60 s)	*Escherichia coli*	2.1	3/3	[48]
	Hydrogen peroxide (H_2O_2) (2% for 90 s)	*Escherichia coli* O157:H7	4.3	0/3	[97]
		Salmonella enteritidis	4.3	0/3	
	Aqueous ozone (O_3) (3 ppm for 5 min)	*Escherichia coli* O157:H7,	5.9	0/5	[56]
		Listeria monocytogenes	5.9		
	ClO_2 (3 ppm, 5 min)	*Escherichia coli* O157:H7,	5.8		
		Listeria monocytogenes	6.0		
	Plant extract (grape stem extract, 25 mg/mL)	*Escherichia coli* O157:H7	0.7	0/5	[98]
		Salmonella enterica	1.0	0/5	
		Listeria monocytogenes	0.8	0/5	

Table 6. *Cont.*

Vegetables	Non-Chlorine Sanitizers (Conc. and Contact Time)	Microorganisms	Maximum Reduction (log CFU/g)	Complete Reduction/Number of Samples	References
Tomato	PAA at 100 mg/L (5 min@65 rpm) (laboratory scale)	*Escherichia coli* O157:H7,	5.5	3/6	[69]
		Salmonella typhimurium DT104	6.8	6/6	
		Listeria monocytogenes	2.4	0/6	
	Lactic acid (2%) (5 min@65 rpm)	*Escherichia coli* O157:H7,	2.4	0/6	
		Salmonella typhimurium DT104	4.8	0/6	
		Listeria monocytogenes	2.3	0/6	
	ClO_2 (5 mg/L, 60 s) (commercial scale)	*Salmonella* spp.	4.9	0/15	[77]
	PAA (80 mg/L, 60 s) (commercial scale)	*Salmonella* spp.	5.5	15/15	[89]
	Calcinated calcium (1 min, 0.01%)	*Escherichia coli* O157:H7	7.6	0/3	[48]
		Salmonella spp.	7.4		
		Listeria monocytogenes	7.5		
	H_2O_2 (5% for 2 min, 60 °C)	*Salmonella* spp.	2.6	0/3	[97]
		Escherichia coli	1.4		
		Listeria monocytogenes	2.5		
	Aqueous O_3 (0.45 ppm for 10 min)	*Salmonella* spp.	4.5	0/6	[99]
	Green tea extract (60%; 5 min)	*Escherichia coli*	5.66 ± 0.1	3/3	[68]
		Salmonella enteriditis	5.23 ± 0.12	0/3	
Cucumber	Peracetic acid (PAA) (0.5%)	*Salmonella typhimurium*	2.66 ± 0.20	0/12	[74]
		Listeria monocytogenes	1.28 ± 0.35		
	Lactic acid (2%)	*Salmonella typhimurium*	2.14 ± 0.26		
		Listeria monocytogenes	0.75 ± 0.43		
	Calcinated calcium (0.01% for 1 min)	*Escherichia coli*	3.62 ± 0.1	3/3	[48]
	H_2O_2 (0.5% for 2 min)	*Salmonella typhimurium*	2.63 ± 0.19	0/12	[100]
		Listeria monocytogenes	1.16 ± 0.40		
	Aqueous O_3 (2% for 5 min)	-	-	-	-
	ClO_2 (100 ppm)	*Escherichia coli*	2.61± 0.1	0/5	[101]
	Green tea extract (60%; 5 min)	*Salmonella enterica*	2.0 ± 0.1	0/4	[52]
		Listeria monocytogenes	2.07 ± 0.1		

Table 6. *Cont.*

Vegetables	Non-Chlorine Sanitizers (Conc. and Contact Time)	Microorganisms	Maximum Reduction (log CFU/g)	Complete Reduction/Number of Samples	References
Carrot	Peracetic acid (PAA) (40 ppm, 1 min)	*Escherichia coli*	0.5	0/4	[102]
		Salmonella spp.	1.5		
		Listeria monocytogenes	0.5		
	Lactic acid (0.1%; 5 min)	*Escherichia coli* O157:H7	0.4	0/5	[103]
	Calcinated calcium (0.01% for 1 min)	*Escherichia coli*	0.5	3/3	[48]
		Salmonella spp.	0.5	3/3	
	H_2O_2 (1.5% for 90 s)	*Escherichia coli*	0.8	0/3	[104]
	Aqueous O_3 (16.5 mg/L)	*Escherichia coli* O157:H7	1.85	0/3	[105,106]
	ClO_2 (20 mg/L)	*Escherichia coli* O157:H7	3.0	0/3	
	Plant extract	-	-	-	-
Green chili	Peracetic acid (PAA)	-	-	-	-
	Lactic acid	-	-	-	-
	Calcinated calcium (0.01% for 1 min)	*Escherichia coli*	0.5	0/3	[48]
		Salmonella spp.	0.5	0/3	
	H_2O_2 (0.5% for 2 min)	*Escherichia coli*	0.5	0/3	[107]
		Salmonella spp.	0.5	0/3	
	Aqueous O_3	-	-	-	
	ClO_2	-	-	-	-
	Plant extract	-	-	-	-
Coriander leaf	Peracetic acid (PAA)	-	-	-	-
	Lactic acid	-	-	-	-
	Calcinated calcium (0.01% for 1 min)	*Escherichia coli*	1.6 ± 0.1	3/3	[48]
	H_2O_2	-	-	-	-
	Aqueous ozone (O_3) (6% for 30 min)	*Escherichiacoli*	2.5	0/3	[108]
		Salmonella typhimurium	2.7	0/3	
	Aqueous ClO_2	-	-	-	-
	Plant extract	-	-	-	-

3. Conclusions

The majority of research has found that irrigation or wash water poses the greatest threat to vegetable food safety, followed by how the crop is treated during the postharvest process. Microbial contamination is a major cause of postharvest losses in fresh vegetables and washing them in water reduces the quantity of microbes on their surface by one or two logs (one log reduction being a 10-fold reduction). The quantity of total dissolved solids (such as soil, dirt, and debris) in the water, the water temperature, the quality of the incoming water (such as pH and mineral content), the contact time with the produce, and the texture of the produce are all variables that influence the effectiveness of the sanitizer in vegetables (smooth or rough surface). As chlorine-based sanitizers pose risks to human health, non-chlorine alternatives have emerged as viable options. Washing fresh vegetables with non-chlorine sanitizers has shown significant reductions in resident aerobic bacteria, total coliform bacteria, yeast, and mold populations. Moreover, these sanitizers effectively reduce pathogenic bacterial populations to below detectable limits. Research findings suggest that all non-chlorine sanitizers can enhance the safety and quality of fresh vegetables. However, among them, 0.01% calcinated calcium emerges as the optimal and safest choice due to its biodegradable nature, organic characteristics, and environmentally friendly properties. Additionally, the majority of sanitizer effectiveness studies have only been conducted in laboratories; it is crucial to validate sanitizers in actual workplace settings. Furthermore, when determining the precise procedure (amount and mode of sanitizer delivery) to handle the vegetables, appropriate sanitation should consider the aforementioned factors.

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References

1. Mir, S.A.; Shah, M.A.; Mir, M.M.; Dar, B.N.; Greiner, R.; Roohinejad, S. Microbiological contamination of ready-to-eat vegetable salads in developing countries and potential solutions in the supply chain to control microbial pathogens. *Food Control* **2018**, *85*, 235–244. [CrossRef]
2. Akoachere, J.F.T.K.; Tatsinkou, B.F.; Nkengfack, J.M. Bacterial and parasitic contaminants of salad vegetables sold in markets in Fako Division, Cameroon and evaluation of hygiene and handling practices of vendors. *BMC Res. Notes* **2018**, *11*, 1–7. [CrossRef]
3. Sagoo, S.K.; Little, C.L.; Ward, L.; Gillespie, I.A.; Mitchell, R.T. Microbiological study of ready-to-eat salad vegetables from retail establishments uncovers a national outbreak of salmonellosis. *J. Food Prot.* **2003**, *66*, 403–409. [CrossRef]
4. Marshall, K.M.; Nowaczyk II, L.; Raphael, B.H.; Skinner, G.E.; Reddy, N.R. Identification and genetic characterization *of Clostridium botulinum* serotype A strains from commercially pasteurized carrot juice. *Food Microbiol.* **2014**, *44*, 149–155. [CrossRef]
5. Mazaheri, S.; Ahrabi, S.S.; Aslani, M.M. Shiga toxin-producing *Escherichia coli* isolated from lettuce samples in Tehran, Iran. *Jundishapur J. Microbiol.* **2014**, *7*, e12346. [CrossRef]
6. Tahir, U.; Zameer, M.; Zahra, N.; Mazhar, M.; Rafique, A.; Alyas, S.; Akram, Q. Isolation and Characterization of Shiga-toxigenic *Escherichia coli* Isolated from Various Food Samples. *J. Food Nutr. Res.* **2022**, *10*, 19–25. [CrossRef]
7. Wei, S.; Park, B.J.; Seo, K.H.; Oh, D.H. Highly efficient and specific separation of *Staphylococcus aureus* from lettuce and milk using Dynabeads protein G conjugates. *Food Sci. Biotechnol.* **2016**, *25*, 1501–1505. [CrossRef]
8. Colombari, V.; Mayer, M.D.; Laicini, Z.M.; Mamizuka, E.; Franco, B.D.; Destro, M.T.; Landgraf, M. Foodborne outbreak caused by *Staphylococcus aureus*: Phenotypic and genotypic characterization of strains of food and human sources. *J. Food Prot.* **2007**, *70*, 489–493. [CrossRef]
9. Denayer, S.; Delbrassinne, L.; Nia, Y.; Botteldoorn, N. Foodborne outbreak investigation and molecular typing: High diversity of *Staphylococcus aureus* strains and importance of toxin detection. *Toxins* **2017**, *9*, 407. [CrossRef]
10. Shenoy, A.G.; Oliver, H.F.; Deering, A.J. *Listeria monocytogenes* internalizes in romaine lettuce grown in greenhouse conditions. *J. Food Prot.* **2017**, *80*, 573–581. [CrossRef]
11. Honjoh, K.I.; Iwaizako, Y.; Lin, Y.; Kijima, N.; Miyamoto, T. Possibilities for contamination of tomato fruit by *Listeria monocytogenes* during cultivation. *Food Sci. Technol. Res.* **2016**, *22*, 349–357. [CrossRef]
12. Ceuppens, S.; Hessel, C.T.; de Quadros Rodrigues, R.; Bartz, S.; Tondo, E.C.; Uyttendaele, M. Microbiological quality and safety assessment of lettuce production in Brazil. *Int. J. Food Microbiol.* **2014**, *181*, 67–76. [CrossRef]
13. Bartz, J.A.; Yuk, H.G.; Mahovic, M.J.; Warren, B.R.; Sreedharan, A.; Schneider, K.R. Internalization of *Salmonella enterica* by tomato fruit. *Food Control* **2015**, *55*, 141–150. [CrossRef]
14. Guchi, B.; Ashenafi, M. Microbial load, prevalence and antibiograms of *Salmonella* and *Shigella* in lettuce and green peppers. *Ethiop. J. Health Sci.* **2010**, *20*. [CrossRef] [PubMed]
15. Rimhanen-Finne, R.; Niskanen, T.; Hallanvuo, S.; Makary, P.; Haukka, K.; Pajunen, S.; Kuusi, M. *Yersinia pseudotuberculosis* causing a large outbreak associated with carrots in Finland, 2006. *Epidemiol. Infect.* **2009**, *137*, 342–347. [CrossRef]
16. Islam, Z.; Sultana, S.; Rahman, M.M.; Rahman, S.R.; Bari, M.L. Effectiveness of different sanitizers in inactivating *E. coli* O157: H7 in Tomato and Cucumber. *J. Food Nutr. Sci.* **2015**, *3*, 60–64. [CrossRef]

17. MacDonald, E.; Heier, B.T.; Nygård, K.; Stalheim, T.; Cudjoe, K.S.; Skjerdal, T.; Vold, L. *Yersinia enterocolitica* outbreak associated with ready-to-eat salad mix, Norway, 2011. *Emerg. Infect. Dis.* **2012**, *18*, 1496. [CrossRef] [PubMed]
18. Coudray-Meunier, C.; Fraisse, A.; Martin-Latil, S.; Guillier, L.; Delannoy, S.; Fach, P.; Perelle, S. A comparative study of digital RT-PCR and RT-qPCR for quantification of Hepatitis A virus and Norovirus in lettuce and water samples. *Int. J. Food Microbiol.* **2015**, *201*, 17–26. [CrossRef]
19. Donnan, E.J.; Fielding, J.E.; Gregory, J.E.; Lalor, K.; Rowe, S.; Goldsmith, P.; Vally, H. A multistate outbreak of hepatitis A associated with semidried tomatoes in Australia, 2009. *Clin. Infect. Dis.* **2012**, *54*, 775–781. [CrossRef]
20. Utaaker, K.S.; Skjerve, E.; Robertson, L.J. Keeping it cool: Survival of *Giardia* cysts and *Cryptosporidium* oocysts on lettuce leaves. *Int. J. Food Microbiol.* **2017**, *255*, 51–57. [CrossRef]
21. Buss, B.F.; Joshi, M.V.; Dement, J.L.; Cantu, V.; Safranek, T.J. Multistate product traceforward investigation to link imported romaine lettuce to a US cyclosporiasis outbreak–Nebraska, Texas, and Florida, June–August 2013. *Epidemiol. Infect.* **2016**, *144*, 2709–2718. [CrossRef]
22. van Elsas, J.D.; Garbeva, P.; Salles, J. Effects of agronomical measures on the microbial diversity of soils as related to the suppression of soil-borne plant pathogens. *Biodegradation* **2002**, *13*, 29–40. [CrossRef]
23. Snyder, A.B.; Worobo, R.W. The incidence and impact of microbial spoilage in the production of fruit and vegetable juices as reported by juice manufacturers. *Food Control* **2018**, *85*, 144–150. [CrossRef]
24. Barth, M.; Hankinson, T.R.; Zhuang, H.; Breidt, F. Microbiological spoilage of fruits and vegetables. In *Compendium of the Microbiological Spoilage of Foods and Beverages*; Springer: New York, NY, USA, 2009; pp. 135–183. [CrossRef]
25. Akbar, A.; Ahmad, M.; Khan, S.Z.; Ahmad, Z. Characterization of the Causal Organism of Soft Rot of Tomatoes and Other Vegetables and Evaluation of Its Most Aggressive Isolates. *Am. J. Plant Sci.* **2015**, *6*, 511–517. [CrossRef]
26. Samuel, O.; Orji, M.U. Fungi associated with the spoilage of postharvest tomato fruits sold in major markets in Awka, Nigeria. *Univers. J. Microbiol. Res.* **2015**, *3*, 11–16. [CrossRef]
27. Lee, D.H.; Kim, J.B.; Kim, M.; Roh, E.; Jung, K.; Choi, M.; Heu, S. Microbiota on spoiled vegetables and their characterization. *J. Food Prot.* **2013**, *76*, 1350–1358. [CrossRef]
28. Luz, C.; D'Opazo, V.; Quiles, J.M.; Romano, R.; Mañes, J.; Meca, G. Biopreservation of tomatoes using fermented media by lactic acid bacteria. *Lwt* **2020**, *130*, 109618. [CrossRef]
29. Tournas, V.H. Spoilage of vegetable crops by bacteria and fungi and related health hazards. *Crit. Rev. Microbiol.* **2005**, *31*, 33–44. [CrossRef]
30. Papoutsis, K.; Edelenbos, M. Postharvest environmentally and human-friendly pre-treatments to minimize carrot waste in the supply chain caused by physiological disorders and fungi. *Trends Food Sci. Technol.* **2021**, *112*, 88–98. [CrossRef]
31. Etebu, E.; Nwauzoma, A.B.; Bawo, D.D.S. Postharvest spoilage of tomato (*Lycopersicon esculentum* Mill.) and control strategies in Nigeria. *J. Biol. Agric. Healthc.* **2013**, *3*, 51–61.
32. Nassarawa, S.S.; Sulaiman, S.A. Extending the shelf life of tomato and onion in Nigeria: A review. *Int. J. Food Sci. Nutr.* **2019**, *4*, 99–111.
33. Alegbeleye, O.; Odeyemi, O.A.; Strateva, M.; Stratev, D. Microbial spoilage of vegetables, fruits and cereals. *Appl. Food Res.* **2022**, *2*, 100122. [CrossRef]
34. Saleh, I.; Al-Thani, R. Fungal food spoilage of supermarkets' displayed fruits. *Vet. World* **2019**, *12*, 1877. [CrossRef] [PubMed]
35. Yaradua, S.S.; Kankara, S.L.; Yusuf, M. Isolation and identification of fungi from some selected vegetables in Kankara local government area, Katsina State. *UMYU J. Microbiol. Res. (UJMR)* **2018**, *3*, 76–80. [CrossRef]
36. Eraky, M.A.; Rashed, S.M.; Nasr, M.E.S.; El-Hamshary, A.M.S.; Salah El-Ghannam, A. Parasitic contamination of commonly consumed fresh leafy vegetables in Benha, Egypt. *J. Parasitol. Res.* **2014**, *2014*, 613960. [CrossRef]
37. Rahman, J.; Talukder, A.I.; Hossain, F.; Mahomud, S.; Islam, M.A.; Shamsuzzoha, M. Detection of *Cryptosporidium* oocyts in commonly consumed fresh salad vegetables. *Am. J. Microbiol. Res.* **2014**, *2*, 224–226. [CrossRef]
38. Pagadala, S.; Marine, S.C.; Micallef, S.A.; Wang, F.; Pahl, D.M.; Melendez, M.V.; Buchanan, R.L. Assessment of region, farming system, irrigation source and sampling time as food safety risk factors for tomatoes. *Int. J. Food Microbiol.* **2015**, *196*, 98–108. [CrossRef]
39. Maffei, D.F.; Alvarenga, V.O.; Sant'Ana, A.S.; Franco, B.D. Assessing the effect of washing practices employed in Brazilian processing plants on the quality of ready-to-eat vegetables. *LWT-Food Sci. Technol.* **2016**, *69*, 474–481. [CrossRef]
40. Lambertini, E.; Buchanan, R.L.; Narrod, C.; Pradhan, A.K. Transmission of bacterial zoonotic pathogens between pets and humans: The role of pet food. *Crit. Rev. Food Sci. Nutr.* **2016**, *56*, 364–418. [CrossRef]
41. Zaman, S.; Aziz, A.; Khaleque, A.S.M.A.; Bari, M.L. Non-Chlorine Sanitizer Enhances the Food Safety of Common Fresh Salad Vegetables. In Proceedings of the 5th AFSA2022 Conference at the Industrial University, Ho Chi Minh City (IUH), Vietnam, 24–27 November 2022; pp. 130–141.
42. Jing, J.L.J.; Pei Yi, T.; Bose, R.J.; McCarthy, J.R.; Tharmalingam, N.; Madheswaran, T. Hand sanitizers: A review on formulation aspects, adverse effects, and regulations. *Int. J. Environ. Res. Public Health* **2020**, *17*, 3326. [CrossRef]
43. Fatica, M.K.; Schneider, K.R. The use of chlorination and alternative sanitizers in the produce industry. *CABI Rev.* **2009**, *4*, 1–10. [CrossRef]
44. Yeomans, D.; Quiñones-Rivera, A. Considerations Toward Lower Toxicity Cleaning in K-12 Schools. *J. Environ. Health* **2021**, *84*, 32.

45. Praeger, U.; Herppich, W.B.; Hassenberg, K. Aqueous chlorine dioxide treatment of horticultural produce: Effects on microbial safety and produce quality–A review. *Crit. Rev. Food Sci. Nutr.* **2018**, *58*, 318–333. [CrossRef] [PubMed]
46. Aaliya, B.; Sunooj, K.V.; Navaf, M.; Akhila, P.P.; Sudheesh, C.; Mir, S.A.; George, J. Recent trends in bacterial decontamination of food products by hurdle technology: A synergistic approach using thermal and non-thermal processing techniques. *Food Res. Int.* **2021**, *147*, 110514. [CrossRef] [PubMed]
47. Ahmed, S.; Siddique, M.A.; Rahman, M.; Bari, M.L.; Ferdousi, S. A study on the prevalence of heavy metals, pesticides, and microbial contaminants and antibiotics resistance pathogens in raw salad vegetables sold in Dhaka, Bangladesh. *Heliyon* **2019**, *5*, e01205. [CrossRef] [PubMed]
48. Bari, M.L.; Inatsu, Y.; Kawasaki, S.; Nazuka, E.; Isshiki, K. Calcinated calcium killing of *Escherichia coli* O157: H7, *Salmonella*, and *Listeria monocytogenes* on the surface of tomatoes. *J. Food Prot.* **2002**, *65*, 1706–1711. [CrossRef] [PubMed]
49. Banach, J.L.; van Overbeek, L.S.; Groot, M.N.; Van der Zouwen, P.S.; Van der Fels-Klerx, H.J. Efficacy of chlorine dioxide on *Escherichia coli* inactivation during pilot-scale fresh-cut lettuce processing. *Int. J. Food Microbiol.* **2018**, *269*, 128–136. [CrossRef]
50. McWatters, K.H.; Doyle, M.P.; Walker, S.L.; Rimal, A.P.; Venkitanarayanan, K. Consumer acceptance of raw apples treated with an antibacterial solution designed for home use. *J. Food Prot.* **2002**, *65*, 106–110. [CrossRef] [PubMed]
51. Arslan-Alaton, I.; Olmez-Hanci, T.; Gursoy, B.H.; Tureli, G. H_2O_2/UV-C treatment of the commercially important aryl sulfonates H-, K-, J-acid and Para base: Assessment of photodegradation kinetics and products. *Chemosphere* **2009**, *76*, 587–594. [CrossRef]
52. Ramos, B.; Miller, F.A.; Brandão, T.R.S.; Teixeira, P.; Silva, C.L.M. Fresh fruits and vegetables—An overview on applied methodologies to improve its quality and safety. *Innov. Food Sci. Emerg. Technol.* **2013**, *20*, 1–15. [CrossRef]
53. Picchioni, G.A.; Watada, A.E.; Whitaker, B.D.; Reyes, A. Calcium delays senescence-related membrane lipid changes and increases net synthesis of membrane lipid components in shredded carrots. *Postharvest Biol. Technol.* **1996**, *9*, 235–245. [CrossRef]
54. Brodowska, A.J.; Nowak, A.; Śmigielski, K. Ozone in the food industry: Principles of ozone treatment, mechanisms of action, and applications: An overview. *Crit. Rev. Food Sci. Nutr.* **2018**, *58*, 2176–2201. [CrossRef] [PubMed]
55. Anino, S.V.; Salvatori, D.M.; Alzamora, S.M. Changes in calcium level and mechanical properties of apple tissue due to impregnation with calcium salts. *Food Res. Int.* **2006**, *39*, 154–164. [CrossRef]
56. Alexandre, E.M.; Santos-Pedro, D.M.; Brandão, T.R.; Silva, C.L. Influence of aqueous ozone, blanching and combined treatments on microbial load of red bell peppers, strawberries and watercress. *J. Food Eng.* **2011**, *105*, 277–282. [CrossRef]
57. Ölmez, H.; Kretzschmar, U. Potential alternative disinfection methods for organic fresh-cut industry for minimizing water consumption and environmental impact. *LWT-Food Sci. Technol.* **2009**, *42*, 686–693. [CrossRef]
58. Akbas, M.Y.; Ölmez, H. Inactivation of *Escherichia coli* and *Listeria monocytogenes* on iceberg lettuce by dip wash treatments with organic acids. *Lett. Appl. Microbiol.* **2007**, *44*, 619–624. [CrossRef] [PubMed]
59. Uddin, M.N.; Zaman, S.; Aziz, A.; Yamamoto, K.; Nakaura, Y.; Bari, M.L. Microbial Safety, Visual Quality and Consumers' Perception of Minimally-Processed Ready-to-eat Salad Vegetables Prepared and Stored at Room and Refrigeration Temperature. *Bangladesh J. Microbiol.* **2021**, *38*, 51–62. [CrossRef]
60. Neo, S.Y.; Lim, P.Y.; Phua, L.K.; Khoo, G.H.; Kim, S.J.; Lee, S.C.; Yuk, H.G. Efficacy of chlorine and peroxyacetic acid on reduction of natural microflora, *Escherichia coli* O157: H7, *Listeria monocyotgenes* and *Salmonella* spp. on mung bean sprouts. *Food Microbiol.* **2013**, *36*, 475–480. [CrossRef] [PubMed]
61. Miao, Y.; Zhang, H.; Zhang, L.; Wu, S.; Sun, Y.; Shan, Y.; Yuan, Y. Acrylamide and 5-hydroxymethylfurfural formation in reconstituted potato chips during frying. *J. Food Sci. Technol.* **2014**, *51*, 4005–4011. [CrossRef]
62. Gombas, D.; Luo, Y.; Brennan, J.; Shergill, G.; Petran, R.; Walsh, R.; Deng, K. Guidelines to validate control of cross-contamination during washing of fresh-cut leafy vegetables. *J. Food Prot.* **2017**, *80*, 312–330. [CrossRef]
63. Marmot, M.; Atinmo, T.; Byers, T.; Chen, J.; Hirohata, T.; Jackson, A.; Zeisel, S. Food, nutrition, physical activity, and the prevention of cancer: A global perspective. 2007. Available online: https://www3.paho.org/hq/dmdocuments/2011/nutrition-AICR-WCR-food-physical-activ.pdf (accessed on 1 May 2024).
64. Cazón, P.; Velazquez, G.; Ramírez, J.A.; Vázquez, M. Polysaccharide-based films and coatings for food packaging: A review. *Food Hydrocoll.* **2017**, *68*, 136–148. [CrossRef]
65. Martín-Diana, A.B.; Rico, D.; Barry-Ryan, C.; Frías, J.M.; Mulcahy, J.; Henehan, G.T. Comparison of calcium lactate with chlorine as a washing treatment for fresh-cut lettuce and carrots: Quality and nutritional parameters. *J. Sci. Food Agric.* **2005**, *85*, 2260–2268. [CrossRef]
66. Nascimento, R.C.; SÃO JOSÉ, J.F.B.D. Green tea extract: A proposal for fresh vegetable sanitization. *Food Sci. Technol.* **2022**, *42*. [CrossRef]
67. Borges, G.; Lean, M.E.; Roberts, S.A.; Crozier, A. Bioavailability of dietary (poly) phenols: A study with ileostomists to discriminate between absorption in small and large intestine. *Food Funct.* **2013**, *4*, 754–762. [CrossRef] [PubMed]
68. Wu, J.; Chen, S.; Ge, S.; Miao, J.; Li, J.; Zhang, Q. Preparation, properties and antioxidant activity of an active film from silver carp (*Hypophthalmichthys molitrix*) skin gelatin incorporated with green tea extract. *Food Hydrocoll.* **2013**, *32*, 42–51. [CrossRef]
69. Xylia, P.; Chrysargyris, A.; Miltiadous, P.; Tzortzakis, N. Origanum dubium (*Cypriot oregano*) as a Promising Sanitizing Agent against *Salmonella enterica* and *Listeria monocytogenes* on Tomato and Cucumber Fruits. *Biology* **2022**, *11*, 1772. [CrossRef]
70. Zaman, S.; Nahar, Q.; Al-Mamun, A.; Ahmed, R.; Bari, M.L. Use of non-chlorine sanitizer in eliminating bacterial and fungal pathogens from betel leaves-A field level study. *J. Agric. Food Res.* **2021**, *6*, 100198. [CrossRef]

71. Ramos, C.L.; Thorsen, L.; Schwan, R.F.; Jespersen, L. Strain-specific probiotics properties of *Lactobacillus fermentum*, *Lactobacillus plantarum* and *Lactobacillus brevis* isolates from Brazilian food products. *Food Microbiol.* **2013**, *36*, 22–29. [CrossRef] [PubMed]
72. Kim, J.G. Environmental friendly sanitation to improve quality and microbial safety of fresh-cut vegetables. In *Sammour R, Biotechnology–Molecular Studies and Novel Applications for Improved Quality of Human Life*; InTech: Rijeka, Croatia, 2012; pp. 173–196.
73. Fransisca, L.; Zhou, B.; Park, H.; Feng, H. The effect of calcinated calcium and chlorine treatments on *Escherichia coli* O157: H7 87–23 population reduction in radish sprouts. *J. Food Sci.* **2011**, *76*, M404–M412. [CrossRef]
74. Anino, C.; Onyango, A.; Imathiu, S.; Maina, J. Effect of Lactic Acid Bacteria Starter Cultures on Vitamin and Oligosaccharide Composition of Milk Extracted from Three Common Bean (*Phaselous vulgaris* L.) Varieties. 2019. Available online: https://www.ccsenet.org/journal/index.php/jfr/article/view/0/39415 (accessed on 1 May 2024).
75. Chen, Y.C.; Lin, C.L.; Li, C.T.; Hwang, D.F. Structural transformation of oyster, hard clam, and sea urchin shells after calcination and their antibacterial activity against foodborne microorganisms. *Fish. Sci.* **2015**, *81*, 787–794. [CrossRef]
76. Kim, J.G.; Nimitkeatkai, H.; Choi, J.W.; Cheong, S.R. Calcinated calcium and mild heat treatment on storage quality and microbial populations of fresh-cut iceberg lettuce. *Hortic. Environ. Biotechnol.* **2011**, *52*, 408–412. [CrossRef]
77. Sun, X.; Baldwin, E.; Bai, J. Applications of gaseous chlorine dioxide on postharvest handling and storage of fruits and vegetables—A review. *Food Control* **2019**, *95*, 18–26. [CrossRef]
78. D'Amato, S.; Serio, A.; López, C.C.; Paparella, A. Hydrosols: Biological activity and potential as antimicrobials for food applications. *Food Control* **2018**, *86*, 126–137. [CrossRef]
79. Trinh, V.M.; Yuan, M.H.; Chen, Y.H.; Wu, C.Y.; Kang, S.C.; Chiang, P.C.; Hsiao, T.-C.; Huang, H.-P.; Zhao, Y.-L.; Lee, D.M. Chlorine dioxide gas generation using rotating packed bed for air disinfection in a hospital. *J. Clean. Prod.* **2021**, *320*, 128885. [CrossRef]
80. Tzortzakis, N.G. Ethanol, vinegar and *Origanum vulgare* oil vapour suppress the development of anthracnose rot in tomato fruit. *Int. J. Food Microbiol.* **2010**, *142*, 14–18. [CrossRef] [PubMed]
81. Tzortzakis, N.; Chrysargyris, A.; Sivakumar, D.; Loulakakis, K. Vapour or dipping applications of methyl jasmonate, vinegar and sage oil for pepper fruit sanitation towards grey mould. *Postharvest Biol. Technol.* **2016**, *118*, 120–127. [CrossRef]
82. Chrysargyris, A.; Rousos, C.; Xylia, P.; Tzortzakis, N. Vapour application of sage essential oil maintain tomato fruit quality in breaker and red ripening stages. *Plants* **2021**, *10*, 2645. [CrossRef]
83. Xylia, P.; Ioannou, I.; Chrysargyris, A.; Stavrinides, M.C.; Tzortzakis, N. Quality attributes and storage of tomato fruits as affected by an eco-friendly, essential oil-based product. *Plants* **2021**, *10*, 1125. [CrossRef]
84. Engels, C.; Schieber, A.; Gänzle, M.G. Sinapic acid derivatives in defatted Oriental mustard (*Brassica juncea* L.) seed meal extracts using UHPLC-DAD-ESI-MS n and identification of compounds with antibacterial activity. *Eur. Food Res. Technol.* **2012**, *234*, 535–542. [CrossRef]
85. Poimenidou, S.V.; Bikouli, V.C.; Gardeli, C.; Mitsi, C.; Tarantilis, P.A.; Nychas, G.J.; Skandamis, P.N. Effect of single or combined chemical and natural antimicrobial interventions on *Escherichia coli* O157: H7, total microbiota and color of packaged spinach and lettuce. *Int. J. Food Microbiol.* **2016**, *220*, 6–18. [CrossRef] [PubMed]
86. Tiwari, B.K.; Valdramidis, V.P.; O'Donnell, C.P.; Muthukumarappan, K.; Bourke, P.; Cullen, P.J. Application of natural antimicrobials for food preservation. *J. Agric. Food Chem.* **2009**, *57*, 5987–6000. [CrossRef] [PubMed]
87. Deng, L.J.; Qi, M.; Li, N.; Lei, Y.H.; Zhang, D.M.; Chen, J.X. Natural products and their derivatives: Promising modulators of tumor immunotherapy. *J. Leucoc. Biol.* **2020**, *108*, 493–508. [CrossRef] [PubMed]
88. Randazzo, W.; Falcó, I.; Aznar, R.; Sánchez, G. Effect of green tea extract on enteric viruses and its application as natural sanitizer. *Food Microbiol.* **2017**, *66*, 150–156. [CrossRef] [PubMed]
89. Singh, P.; Hung, Y.C.; Qi, H. Efficacy of peracetic acid in inactivating foodborne pathogens on fresh produce surface. *J. Food Sci.* **2018**, *83*, 432–439. [CrossRef] [PubMed]
90. Feroz, F.; Senjuti, J.D.; Noor, R. Determination of microbial growth and survival in salad vegetables through in vitro challenge test. *Int. J. Nutr. Food Sci.* **2013**, *2*, 312–319. [CrossRef]
91. Lin, S.; Huff, H.E.; Hsieh, F. Extrusion process parameters, sensory characteristics, and structural properties of a high moisture soy protein meat analog. *J. Food Sci.* **2002**, *67*, 1066–1072. [CrossRef]
92. Rodgers, S.L.; Cash, J.N.; Siddiq, M.; Ryser, E.T. A comparison of different chemical sanitizers for inactivating *Escherichia coli* O157: H7 and *Listeria monocytogenes* in solution and on apples, lettuce, strawberries, and cantaloupe. *J. Food Prot.* **2004**, *67*, 721–731. [CrossRef] [PubMed]
93. Sánchez, N.; Lee-Rangel, H.A.; Martínez-Cortés, I.; Mendoza, G.D.; Hernández, P.A.; Espinoza, E.; Relling, A.E. A polyherbal phytogenic additive improved growth performance, health, and immune response in dairy calves. *Food Agric. Immunol.* **2021**, *32*, 482–498. [CrossRef]
94. Chang, A.S.; Schneider, K.R. Evaluation of overhead spray-applied sanitizers for the reduction of *Salmonella* on tomato surfaces. *J. Food Sci.* **2012**, *77*, M65–M69. [CrossRef]
95. Sapers, G.M.; Jones, D.M. Improved sanitizing treatments for fresh tomatoes. *J. Food Sci.* **2006**, *71*, M252–M256. [CrossRef]
96. Xu, W.; Wu, C. Different efficiency of ozonated water washing to inactivate *Salmonella enterica* Typhimurium on green onions, grape tomatoes, and green leaf lettuces. *J. Food Sci.* **2014**, *79*, M378–M383. [CrossRef]
97. Augspole, I.; Rakcejeva, T. Effect of hydrogen peroxide on the quality parameters of shredded carrots. In Proceedings of the Annual 19th International Scientific Conference Research for Rural Development, Jelgava, Latvia, 15–17 May 2013; Volume 1, pp. 91–97.

98. Anastasiadi, M.; Pratsinis, H.; Kletsas, D.; Skaltsounis, A.L.; Haroutounian, S.A. Grape stem extracts: Polyphenolic content and assessment of their in vitro antioxidant properties. *LWT-Food Sci. Technol.* **2012**, *48*, 316–322. [CrossRef]
99. Singh, N.; Singh, R.K.; Bhunia, A.K.; Stroshine, R.L. Efficacy of chlorine dioxide, ozone, and thyme essential oil or a sequential washing in killing *Escherichia coli* O157: H7 on lettuce and baby carrots. *LWT* **2002**, *35*, 720–729. [CrossRef]
100. Sun, Y.; Wang, H.; Liu, S.; Peng, X. Exogenous application of hydrogen peroxide alleviates drought stress in cucumber seedlings. *S. Afr. J. Bot.* **2016**, *106*, 23–28. [CrossRef]
101. Hwang, C.A.; Huang, L.; Wu, V.C.H. In situ generation of chlorine dioxide for surface decontamination of produce. *J. Food Prot.* **2017**, *80*, 567–572. [CrossRef]
102. Vandekinderen, I.; Devlieghere, F.; Van Camp, J.; Denon, Q.; Alarcon, S.S.; Ragaert, P.; De Meulenaer, B. Impact of a decontamination step with peroxyacetic acid on the shelf-life, sensory quality and nutrient content of grated carrots packed under equilibrium modified atmosphere and stored at 7 C. *Postharvest Biol. Technol.* **2009**, *54*, 141–152. [CrossRef]
103. Gyawali, R.; Ibrahim, S.A. Synergistic effect of copper and lactic acid against *Salmonella* and *Escherichia coli* O157: H7: A review. *Emir. J. Food Agric.* **2012**, *24*, 1–11.
104. Szopinska, D.; Jarosz, M.; Slawinska, B. The effect of hydrogen peroxide on seed quality and emergence of carrot (*Daucus carota* L.). *Acta Sci. Polonorum. Hortorum Cultus* **2017**, *16*, 21–33.
105. de Souza, L.P.; Faroni, L.R.D.A.; Heleno, F.F.; Cecon, P.R.; Gonçalves, T.D.C.; da Silva, G.J.; Prates, L.H.F. Effects of ozone treatment on postharvest carrot quality. *LWT* **2018**, *90*, 53–60. [CrossRef]
106. Li, K.; Chiu, Y.C.; Jiang, W.; Jones, L.; Etienne, X.; Shen, C. Comparing the efficacy of two triple-wash procedures with sodium hypochlorite, a lactic–citric acid blend, and a mix of peroxyacetic acid and hydrogen peroxide to inactivate *Salmonella*, *Listeria monocytogenes*, and surrogate *Enterococcus faecium* on cucumbers and tomatoes. *Front. Sustain. Food Syst.* **2020**, *4*, 19.
107. Khadiza, A.R. Effectiveness of Non-Chlorine Sanitizers on Green Chilli, and Coriander Leaf of Dhaka City. Master's Thesis, Department of Microbiology, Jagannath University, Dhaka, Bangladesh, 2018.
108. Gibson, K.E.; Almeida, G.; Jones, S.L.; Wright, K.; Lee, J.A. Inactivation of bacteria on fresh produce by batch wash ozone sanitation. *Food Control* **2019**, *106*, 106747. [CrossRef]