PhageGuard

THE POWER OF NATURE

How phages can protect fresh and frozen fruits and vegetables against Listeria, Salmonella and E. coli

Content

1 Summary

The role of fresh fruits and vegetables in nutritious and healthy diets is well recognized. Consumers appreciate fruits and vegetables for their convenience and wholesomeness and for adding a variety of tastes and colors to their plate. This, along with increasing consumer demands for variety and availability has led to an increase in international trade in these products.

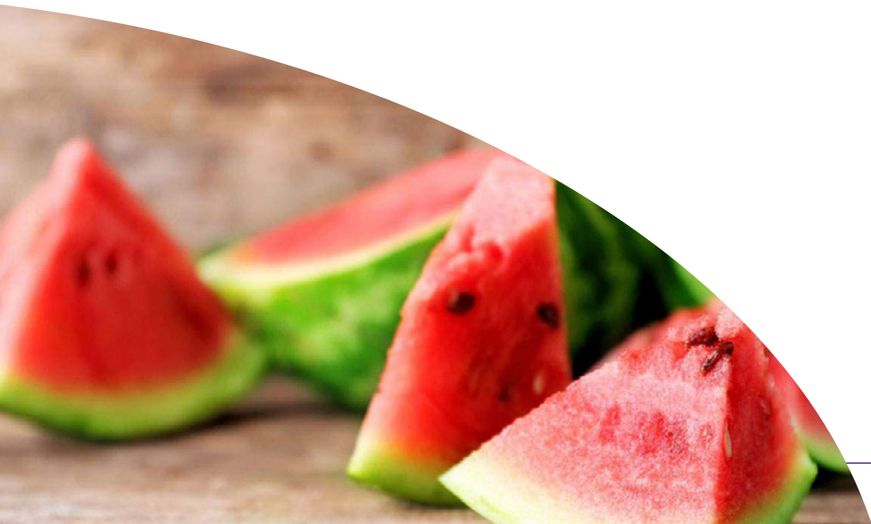
Fresh produce (fruit and vegetables) however also continue to be a major source of foodborne illness outbreaks implicating pathogens such as *Escherichia coli* O157:H7, *Salmonella* and *Listeria monocytogenes*. Previously, outbreaks were primarily limited to leafy greens, tomatoes, and cantaloupes, but more recently there has been a trend of more diverse produce types (e.g. cucumbers and papayas) being implicated. On-farm good agricultural practices (GAP) contribute to preventing pathogens from entering the fresh produce chain; however, they cannot be relied upon completely to ensure a safe food supply. Moreover, post-harvest processing often offers conditions for cross contamination, including the exposure of product to *Listeria* biofilms.

Multiple washing steps and food safety intervention hurdles are needed to reduce the natural microbial load as well as to reduce the level of pathogens thus enhancing the safety of fresh and frozen produce to protect the health of the consumer.

Phages are the natural enemy of bacteria. PhageGuard products can help produce processors to reduce their pathogen risks on the product itself as well as on processing equipment and in the plant environment. 1 to 3 log reductions can be expected when applied directly on product. Also, *Listeria* reductions can be expected within 2-5 log when applied on critical process equipment (food contact surfaces) such as slicers and belts and on hot spots. PhageGuard is OMRI listed and can be used for certified organic products. PhageGuard is generally recognized as safe (GRAS), and is considered to be a processing aid, hence no labeling is required. Unlike chemicals, phages do not react away with food debris, therefore perfectly equipped as an additional hurdle to combat biofilms.

2 Introduction

Fresh produce remains the leading cause of foodborne illness outbreaks surpassing the typical vehicles for pathogen carriage such as meat, dairy, and seafood [1]. There have been over 400 outbreaks linked to fresh produce since 1990. Sprouted seeds such as alfalfa, clover, and mung beans have commonly been a cause of foodborne illness outbreaks linked to *Salmonella*, STEC, or *L. monocytogenes* [2, 3]. Examples of these outbreaks include fresh produce-related outbreaks such as leafy greens, tomatoes, cantaloupes, and soft fruits (Table 1). Because of its nature, all types of fresh produce have the potential to become contaminated with human pathogens. The increased globalization of the fresh produce supply, increased consumption and aging population, might also be underlying reasons for the diversification of pathogens involved in these outbreaks [4]. Yet, the enhanced sensitivity and selectivity of pathogen diagnostics is a major contribution. Source attribution of pathogens has increased to over 70%; before the advent of sequencing, this was estimated to be in the order of 20%. The net result is that contaminated produce is more likely to be detected, thereby resulting in more recalls. In case of an outbreak, it is now easier to trace this back to the source [5]. All in all, there is an increased incentive to find more effective intervention methods for fresh produce sector.



Vegetables growing in the fields are exposed to multiple sources of contamination. For example, fields where produce is grown are subjected to insects and animals. Fruits and vegetables that grow in dirt can be fertilized with compost. Insects and birds fly around and may carry pathogenic bacteria. Wildlife inhabit even fenced fields and defecate in rivers and lakes that are used to irrigate the nearby farms. Birds are a major contributing factor.

Previously, it was assumed that the post-harvest wash step was sufficient to remove field-acquired contamination. To this end, much of the research performed focused on evaluating or formulating the effectiveness of sanitizers (6). However, it has become evident that post-harvest washing under commercial conditions is not enough and other factors can potentially lead to cross-contamination events. Studies have demonstrated that washing using potable water can reduce the number of cells by 1-2 log, however, it will not eliminate subsurface organisms, and cannot be relied upon as a 'kill step' (7, 8). Wash water antimicrobials, such as chlorine, ozone, chlorine dioxide, peracetic acid, or other chemicals, are important to prevent cross-contamination in the water but have been shown to improve microbiological reduction by only a small amount, and should not be relied on for pathogen reduction on raw produce (9). Consequently, the current philosophy related to ensuring the food safety of fresh produce is to prevent contamination in the field and to minimize cross-contamination during post-harvest handling. In summary, preventing contamination in fields or greenhouses is challenging and even good agricultural practices (GAPs) are insufficient to ensure that human pathogens are not introduced into the fresh produce chain (10).
There is a need for a more effective post-harvest intervention that can replace or supplement post-harvest washing (11).

3 Pathogens of Concern

Listeria monocytogenes, Shiga toxin-producing *Escherichia coli* (STEC) and *Salmonella* may cause disease in humans. They are frequently present in the environment, soil, vegetation or animal feces and flourish in water. Fruits and vegetables become contaminated with soil, mud or water particles that contains the bacteria. Vegetables that grow in the soil, like beets, carrots, and potatoes can come in contact with pathogens in the soil. Other vegetables such as zucchini and other types of squash grow on low-lying vines. The open nature of the fresh produce chain means that contamination can be introduced at various points in production, harvesting and processing, and then passed to the consumer [3].

3.1 STECS

STEC infections are predominant in the U.S. through the food chain *Escherichia coli* O157:H7 can cause a variety of human diseases such as mild diarrhea, hemorrhagic colitis, hemolytic uremic syndrome and thrombotic thrombocytopenic purpura. The bacterium was identified in 1983 and quickly became one of the most important foodborne pathogens [12]. In the last few years, several outbreaks reported *E. coli* linked with baby spinach and lettuce consumption [13].

Two *E. coli* O157:H7 outbreaks in 2018 in the US and Canada involved romaine lettuce infecting more than 300 people with over 100 hospitalized and 5 deaths (FDA). The outbreak strain was found in canal water and sediment collected within an agricultural water reservoir. This is an example of food pathogens entering the food chain from its agricultural source. These recalls had huge commercial impact on the growers. Consumers were warned not to purchase or eat any type of Romaine lettuce or value added product from this crop regardless to the place of origin or date when it was purchased.

3.2 *Salmonella*

Salmonellosis is often associated with the consumption of contaminated food with typical symptoms in humans ranging from diarrhea to systemic typhoid fever [(13)]. *Salmonella* outbreaks have been linked to seed sprouts, cantaloupes, unpasteurized fruit juice, watermelons, mango and tomatoes [(14)]. Examples of recent outbreaks include *Salmonella* on pre-cut melon, sprouts and papayas (CDC). Recalls originate from both the field and processing.

3.3 *Listeria*

Listeria monocytogenes is a pathogen linked with foodborne outbreaks that have included products such as red bell peppers, romaine lettuce, sprouts, apple slices and processed and mixed fruits and vegetables [(15)]. It is widely present in agricultural production environments, and it is implicated in the contamination of fresh crop produce. *L. monocytogenes* occurrence is ubiquitous and compared to most other microorganisms the risk for contamination is increased with its ability to grow or survive in chilled environments. Produce operations (both fresh-cut and packinghouses) with old infrastructure were not necessarily designed with this type of food safety concerns in mind. *Listeria* spp. have a preference for damp places found throughout the processing plant. It will proliferate in unsanitary conditions. It can colonize drains, cooling systems and processing equipment and harbor there at length. Bacterial biofilm formation is an important pathway for fresh produce contamination allowing *L. monocytogenes* to persist for long periods thus representing a source of recurrent contamination and great potential for food safety risk. Fresh produce comes into contact with many different kinds of surfaces at different temperatures during processing or transport [(16)].

Several reports have demonstrated that *L. monocytogenes* is commonly present in a wide variety of fresh produce samples. Its consumption causes a condition named Listeriosis that can be dangerous especially in pregnant women, neonates, the elderly and in people with an immune compromised system [(17)]. The disease is characterized by a high mortality rate ranging from 20 to 30% [(18)].

An example of a recent outbreak from a resident isolate that affected 107 countries was traced to Greenyard, a producer of fresh, frozen and prepared fruits and vegetables. Frozen items subject to recall were produced in Greenyard's Hungarian facility in Baja between Aug. 13, 2016, and June 20, 2018. The same strains of *L. monocytogenes* were detected in frozen vegetables produced in 2016, 2017 and 2018. This example suggests that the strains have the ability to persist in the processing plant despite the cleaning and disinfection procedures that were carried out. As of 15 June 2018, 47 cases including nine deaths had been reported. A root cause analyses determined a persistent presence of *Listeria monocytogenes* in one of the freezing tunnels at Greenyard, which consequently caused its close down.

Greenyard has estimated the cost of the recall at $35 million. Company officials said these costs include destruction of the product, transportation, handling, storage, subcontracting, lower cost absorption of the factory, and loss of margin [19].

Table 1. Example of foodborne illnesses outbreaks linked to fresh produce in the US from 2011 to 2019 (source: CDC, 2019)

Year	Source	Pathogen	No. of cases
2019	Pre-cut melon	*Salmonella* Carrau	137
2018	Pre-cut melon	*Salmonella* Adelaide	77
2018	Sprouts	*Salmonella* Montevideo	10
2018	Romaine lettuce	*E. coli* O157:H7	62
2018	Romaine Lettuce	*E. coli* O157:H7	210
2017	Leafy greens	*E. coli* O157:H7	25
2016	Alfalfa Sprouts	*E. coli* O157:H7	11
2016	Alfalfa Sprouts	*Salmonella* Reading and *Salmonella* Abony	36
2017	Papayas	*Salmonella* Kiambu, Thompson, Agona, Gaminara	251
2016	Frozen vegetables	*L. monocytogenes*	9
2016	Packaged Salads	*L. monocytogenes*	19
2015	Tomato	*Salmonella* Newport	115
2015	Cucumbers	*Salmonella* Poona	907
2014	Caramel Apples	*L. monocytogenes*	35
2014	Clover sprouts	*Escherichia coli* O121	19
2014	Cucumbers	*Salmonella* enterica Newport	275
2012	Cucumbers	*Salmonella* enterica Stpaul	84
2012	Mangoes	*Salmonella* Braenderup	
2013	Shredded Lettuce	*E. coli* O157:H7	30
2013	Ready to eat salad	*E. coli* O157:H7	33
2012	spinach/spring mix	*E. coli* O157:H7	33
2012	Romaine Lettuce	*E. coli* O157:H7	24
2012	Cantaloupe	*Salmonella* enterica Typhimurium and Newport	261
2012	Mango	*Salmonella* enterica Braenderup	127
2011	Cantaloupe	*L. monocytogenes*	147
2011	Romaine Lettuce	*E. coli* O157:H7	58
2011	Cantaloupe	*Salmonella* enterica Panama	20
2011	Papaya	*Salmonella* agona	106

3.4 Infectious Dose

Uncertainty is associated with minimum infectious dose data. Gastric fluids can kill bacteria in 15 min with a pH < 3.0 but reduced stomach acidity allows lower infectious doses and certain foods are protective against gastric fluids. The immune status of the individual further plays an important role. Although impossible to determine the exact minimum infectious dose for individuals or even populations, low infectious doses can be expected for high-risk populations.

Although volunteer studies indicate a high infectious dose, outbreak investigations show a range from as low as < 10 to levels up to 10^9 CFU for *Salmonella* cells [20]. In the event of contamination with *E. coli* O157:H7 the concern of the infection is that the infectious dose may be as low as 10 cells (20) per serving. *Listeria* outbreaks have typically had more than 1000 CFU of *L. monocytogenes*/g. Sometimes the number of *L. monocytogenes* exceeded 1-10 million/g. There are examples where ready-to-eat foods sampled at retail outlets carried 1000 and more cfu of *L. monocytogenes*/g without evidence of causing a human infection [21].

4 Organic phage as a tool to kill pathogens

Bacteriophages (‘phages’) are the most abundant microorganism on this planet. Phages are 100 times smaller than bacteria thus cannot be seen under a normal microscope; yet their collective biomass is larger than that of all humans combined. Phages are naturally present in significant numbers in water and foods of various origins. They are harmless to humans, animals, and plants. Phages use bacteria for their replication. Through this mechanism, phages contribute to environmental homeostasis. Without this natural cycle the bacterial species in a biosphere would become dominant. Every 48 hours 50% of the entire global bacterial population is effectively destroyed by phages.

Every species of bacteria is thought to be the host for at least one phage type. Several phages exist that are able to recognize and lyse (kill) a number of different bacterial strains within one specie; they have a ‘broad spectrum’ or a wide host range. Phages by definition are the natural enemies of bacteria, and therefore are logical candidates for targeted control of foodborne bacterial pathogens like *Listeria*, *Salmonella* and *E. coli* O157.

Phage facts:

- Phage kill only bacterial cells (with no impact on plant or animal cells);
- Phage do not cross species or genus boundaries; therefore they will not affect desired bacteria in
  - foods (e.g., starter cultures for cheese and sausage)
  - commensals in the gastrointestinal tract
  - accompanying bacterial flora in the environment – like water treatment units

Phage are composed entirely of proteins and DNA, so their breakdown products consist exclusively of amino acids and nucleotides, both of which are present in abundance in food products.

4.1 Phages are Safe

With respect to their potential application for the biocontrol of undesired pathogens in foods, feeds, and related environments, it should be considered that phages are the most abundant micro-organisms in our environment. They are present in significant numbers in water and foods of various origins, in particular fermented foods [22]. On fresh and processed dairy and meat products, more than 10^8 viable phages per gram are often present [23]. It is a fact that phages are routinely consumed with our food in high numbers. Moreover, phages are also normal commensals of humans and animals, and are especially abundant in the gastrointestinal tract [24, 25]. It is estimated that the human gut contains around one million billion phages, or 10^{15} [26].

In conclusion, bacteriophages are known to be harmless for all other organisms, are species-specific and have been successfully used for over 10 years in the food industry.

4.2 PhageGuard

PhageGuard products are water based phage solutions which contain bacteriophage against specific pathogens. PhageGuard Listex is characterized by its broad spectrum toward *Listeria* strains including *L. monocytogenes* as well as *L. ivanovii*, *L. welshimeri*, *L. seeligeri* and *L. innocua strains*.

PhageGuard S contains two *Salmonella*-specific bacteriophages and is characterized by its broad spectrum toward *Salmonella* strains. PhageGuard S kills all *Salmonella* serovars including those that are antibiotic resistant and USDA's top 20 most virulent strains.

PhageGuard E consists of a cocktail of 2 phages and it is designed to kill O157 with also effects on some O26 and O121 strains.

PhageGuard is an organic and natural antimicrobial intervention. PhageGuard is tasteless and odorless. It has no impact on the organoleptic properties of the treated product and there is no risk in regard to worker's safety. Research done with PhageGuard has proven up to 3 logs reduction or 99.9% on specific pathogens. PhageGuard is an effective hurdle during processing of produce, resulting in safer products. In both laboratory and factory trials PhageGuard has shown to be very effective in combatting *Listeria*, *Salmonella* and *E. coli* O157. On Food Contact surfaces, the use of PhageGuard Listex gives reductions of 2 to 5 log (99 to 99,999%) even in the presence of food debris.

The PhageGuard products are approved for use by the FDA and USDA as a processing aid on produce.

PhageGuard can be applied by using either a spray or dip application. A 1% dilution typically will result in a $2x10^7$ pfu/cm^2 application. PFU or plaque forming units is a measure of the number of particles capable of forming plaques per unit volume. A solution with a concentration of 10^7 PFU/mL indicates that 1 mL of the solution contains 10 million active phages. The amount of phages required per cm^2 depends on the surface treated, the time available and the targeted reduction.
Processing of produce has risks as pathogens can be present on incoming material, in the production environment and on the process equipment. Pathogens may have established themselves in the plant or may be introduced by incoming raw materials, by workers or by the movement of forklifts, bins and the like.

Phages can be used to reduce these risks. PhageGuard effectively kills pathogens in

- Finished product
- Biofilms on processing equipment
- Biofilms and harboring sites in the production environment

According to various research conducted [27, 28], phages do not react away in the presence of food debris. Unlike commonly used sanitation chemicals, phages can be used to combat biofilms. As PhageGuard is food grade, therefore, phages can be used on critical process equipment such as slicers, belts and blades during processing.
When sprayed on belts it protects against pathogens on the belt as well as pathogens on the product surface that touches the belt.

PhageGuard has no influence on the taste, smell or texture of the produce hence it can be delivered by spray or dip applications.

4.3 PhageGuard on Fruits and Vegetables : Overview

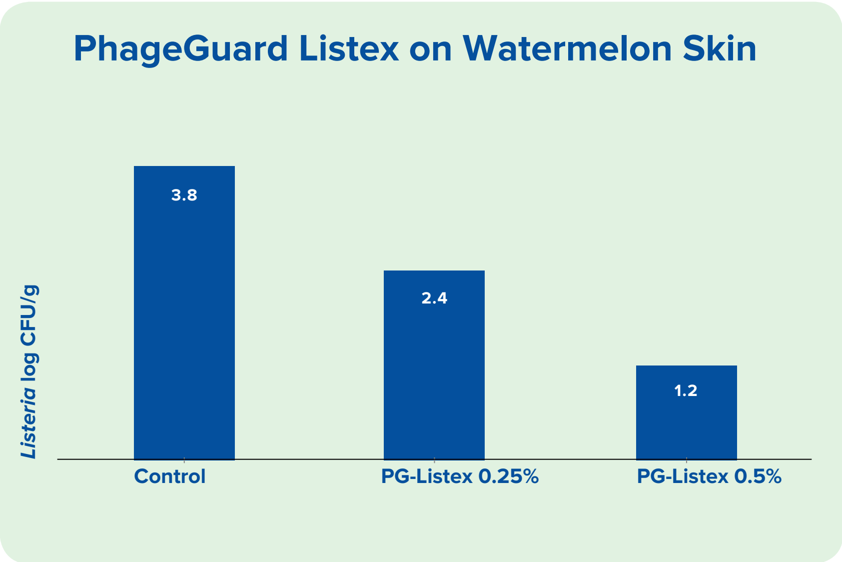
Research has been conducted on a variety of produce to show phage efficacy as can be seen in table 2 below. Micreos data as well as published data have confirmed that PhageGuard interventions provide a 1-3 log reduction of the various pathogens on a large number of different products. The exact reduction will depend on type of product, dose and dwell time after application. The following paragraphs will give more detail on some of the work done on the various products.

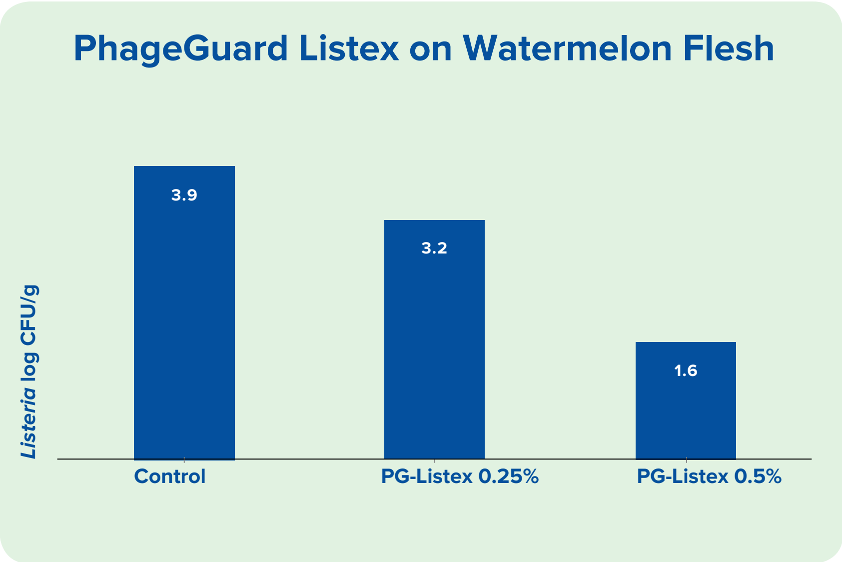
Table 2: Reduction of various pathogens by phage on produce:
Micreos data unless otherwise mentioned

	Listeria	*Salmonella*	*E. coli*
Fruits			
Watermelon flesh	X		
Watermelon skin	X		
Kiwi peel	X		
melon juice (29)	X		
Pear juice (29)	X		
Vegetables			
Romaine Lettuce	X	X	X
Spinach Leaf		X	X
Curly Endive	X		
Zucchini		X	X
Sprouts		X	
Cucumber peel		X	
raw onion	X		
cooked potato wedges	X		
carrots	X		
corn	X		
peas	X		
beans	X		
mushroom	X		
Frozen vegetables			
corn	X		
onion	X		
edamame	X		
peppers	X		
potato	X		

4.4 PhageGuard Listex on Fruits

Watermelon application research: skin and flesh were inoculated with *Listeria monocytogenes* at 2x10^4 CFU/cm^2. These samples were treated with two phage concentrations 0.25% (5x10^6 pfu/cm^2) and 0.5% (10^7 pfu/cm^2). The watermelon samples were then stored at 4°C for 24 hours before enumeration of the bacteria. At the higher dose a > 2 log kill was obtained on both skin and flesh.

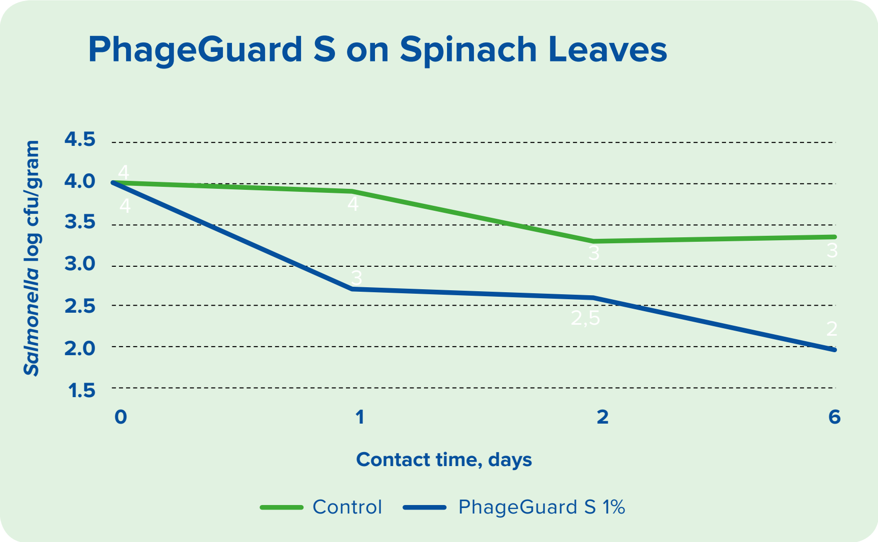




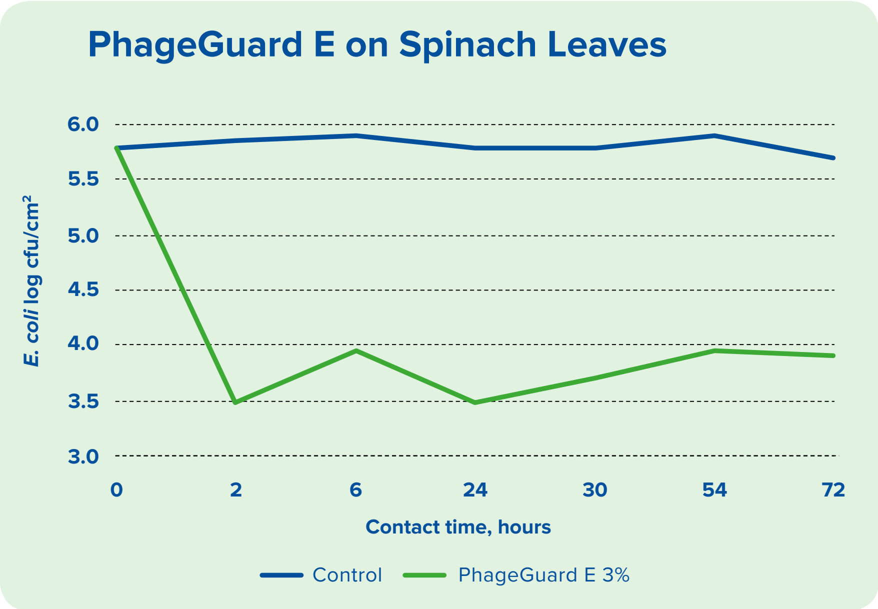
4.5 PhageGuard S and PhageGuard E on Leafy Vegetables

4.5.1 Spinach

Pre-washed spinach was inoculated with $1x10^4$ cfu/cm^2 *Salmonella* and then treated by spraying 1% PhageGuard S ($2x10^7$ pfu/cm^2). The samples were then stored for up to 6 days before enumeration of the bacteria. At this dose a > 1 log kill was obtained when compared to the control.

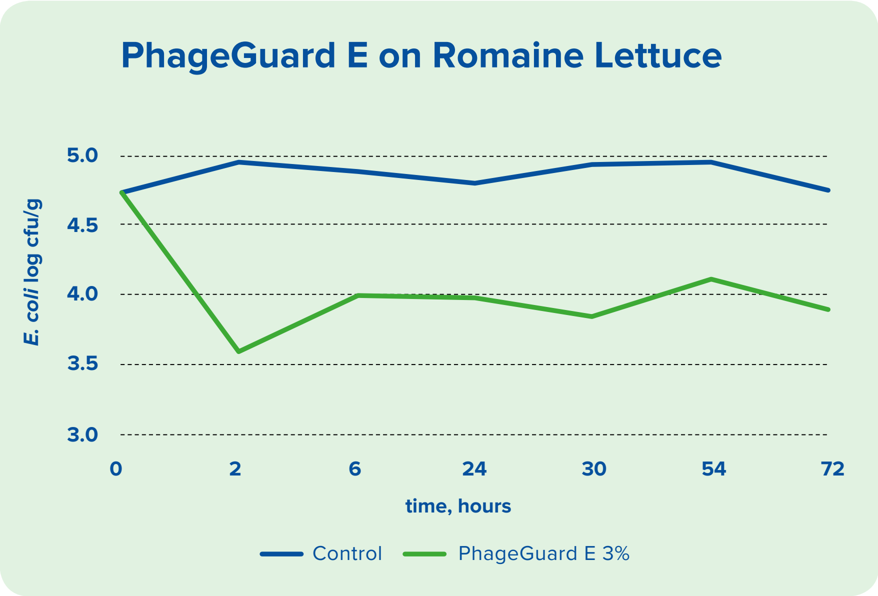


On a second part of the experiment, pre-washed spinach was contaminated with $1x10^6$ cfu/cm^2 *E. coli* and then treated by spraying it with 3% PhageGuard E ($3x10^8$ pfu/cm^2). Within 2 hours, close to 2 log (99%) kill versus the control (rinsed with tap water) was obtained



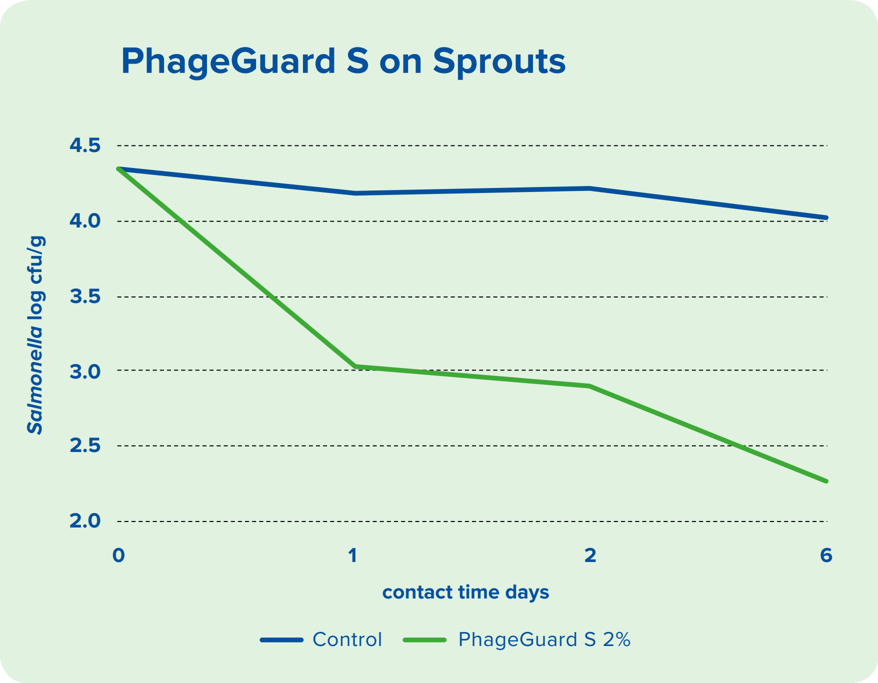
4.5.2 PhageGuard E on Romaine Lettuce

To assess the effectiveness of PhageGuard E on leafy vegetables, romaine lettuce samples were inoculated with different *E. coli* O157 strains at a level of 10^5 CFU/cm^2. Following the contamination, samples were treated with PhageGuard E dilutions to reach 0.3% ($3x10^7$ PFU/cm^2) or 3% ($3x10^8$ PFU/cm^2). Tap water served as the negative control. Samples were incubated for 24 hours at 4°C (39°F) before the *E. coli* O157 cells were retrieved and enumerated. The following data is a representation of an average of three independent experiments with two samples per treatment. This research demonstrated that PhageGuard E is equally effective on all four *E. coli* O157 strains. The addition of more phages resulted in a higher reduction of *E. coli* O157 on leafy vegetables, showing reductions up to 3-log or 99.9%.



4.6 PhageGuard S on Micro Greens

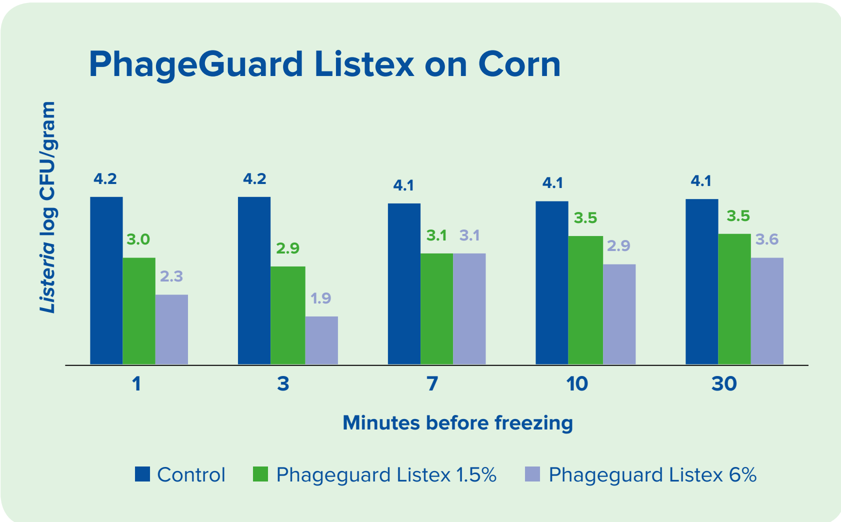
Sprouts were inoculated with 10^4 cfu/cm^2 *Salmonella* followed by a treatment with a 2% solution of PhageGuard S at 0.5 uL/cm^2. The treatment resulted in $2x10^7$ pfu/cm^2 and gave a 2 log reduction (99%).



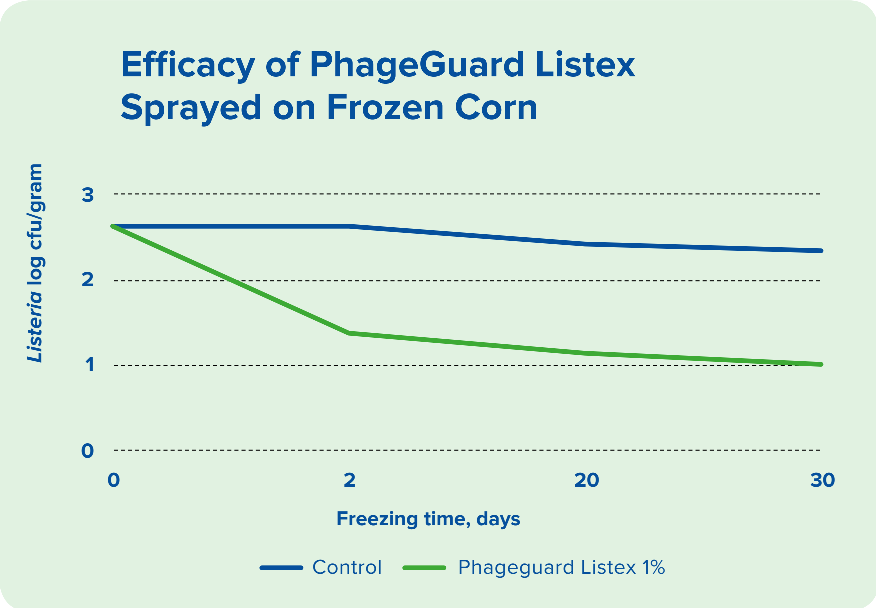
4.7 PhageGuard Listex on Frozen Vegetables

Several experiments on frozen vegetables have been performed resulting in up to 2 log reduction (99%). The application is preferable with a spray bar on a vibrating belt after blanching and before entering the freezer. Alternatively phages can be applied after freezing through spray nozzles that are usually part of the enrober (rotating drum to ensure proper coverage of the phage on the surface of the targeted product, see picture).

The graph shows an application before freezing. At room temperature corn was inoculated with 1 x 10^5 CFU/g of *Listeria monocytogenes* with an attachment time of 5 minutes. PhageGuard Listex was applied at 1.5% and 6% via spray with a 1% pick up, resulting in a dose of 5x10^6 PFU/cm^2 (1.5%) and 2x10^7 PFU/cm^2 (6%). Tap water was used as control. After hold times of respectively 1, 3, 7, 10 or 30 minutes the corn was frozen at -27°C (-16°F) for 5-8 hours. Results show that there is more than 1 log kill at 1 minute - at the low dose and more than 2 log kill at the high dose and no significance between the 1 and 30 minute time points. As such, 1 minute is sufficient between application and freezing.



The graph below shows an application of phage after freezing on vegetables. Frozen corn kernels were inoculated and subsequently treated with PhageGuard Listex while they remained frozen. A 1% dilution and 2% pick-up allowed for a phage concentration of 7x10^6 pfu/cm^2. Samples were kept frozen for 1, 10 and 30 days; at each time point corn was defrosted and kept for 4 hours. The use of PhageGuard Listex on frozen corn demonstrated a reduction of more than 1 log (90%) compared to the control, regardless the frozen storage time.



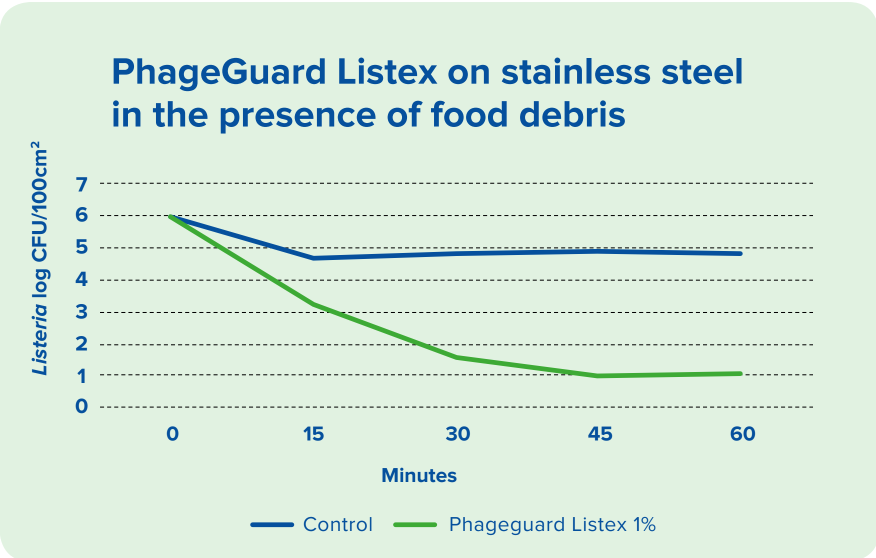
4.8 PhageGuard Listex against *Listeria* in the Processing Environment

Listeria monocytogenes is a problem in the processing environment because it forms biofilms which are difficult to dislodge during cleaning. Biofilms are complex in nature and they provide bacterial cells with protection against sanitizers. A listericidal or kill step is important for eliminating *L. monocytogenes* during the processing of foods as well as controlling *L. monocytogenes* in the processing environment. This is important for preventing post-processing contamination. Research has shown that *L. monocytogenes* found in processed RTE foods often is a result of recontamination, during processing and before final packaging [30, 31, 32].

PhageGuard Listex can help produce processors to reduce their *Listeria* risks on processing equipment and in the environment. A 2-5 log reduction can be expected on equipment such as belts as well as on spots that deem positive during environmental monitoring. These are known as environmental hot spots. For this application, PhageGuard Listex can be used to reduce the threat of cross contamination during processing. It can also help to eliminate biofilms in the production environment and can be used as part of a multi-hurdle approach to ensure that soft metals, such as aluminum fins and coils in refrigeration and freezer units are *Listeria* free.

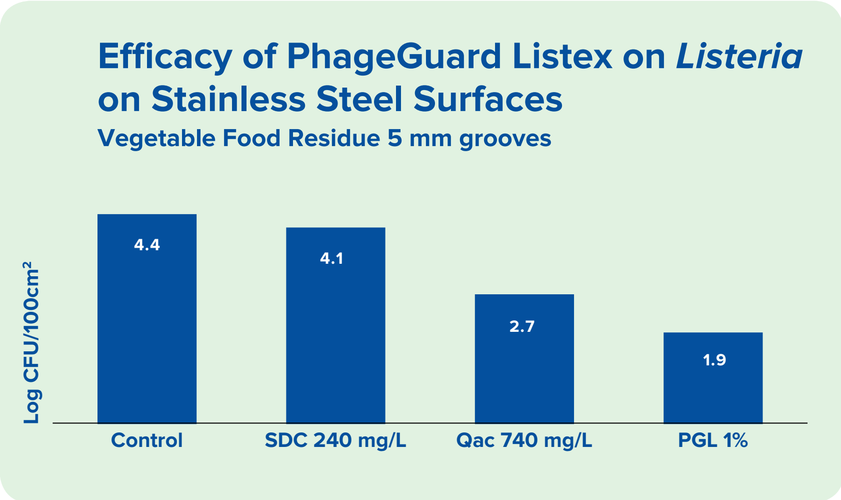
4.8.1 PhageGuard kills *Listeria* Biofilms on Stainless Steel Surface in the Presence of Food Debris

Spraying PhageGuard Listex at 1% ($2x10^7$ pfu/cm^2) reduces *Listeria* numbers by 3-4 log on stainless steel surfaces in the presence of food debris [28]. Mean values are represented for all food samples (10% UHT milk, 100% UHT milk, 10% ham). PhageGuard Listex worked immediate upon application and reached its maximum result within 45 minutes. A perfect application is to use PhageGuard Listex on critical process equipment during processing such as slicers, where it is protecting against cross contamination. Soni at al. [27] found 3.5 to 5.4 log reduction after 2 to 7 days attachment time of the *Listeria* to the surface.



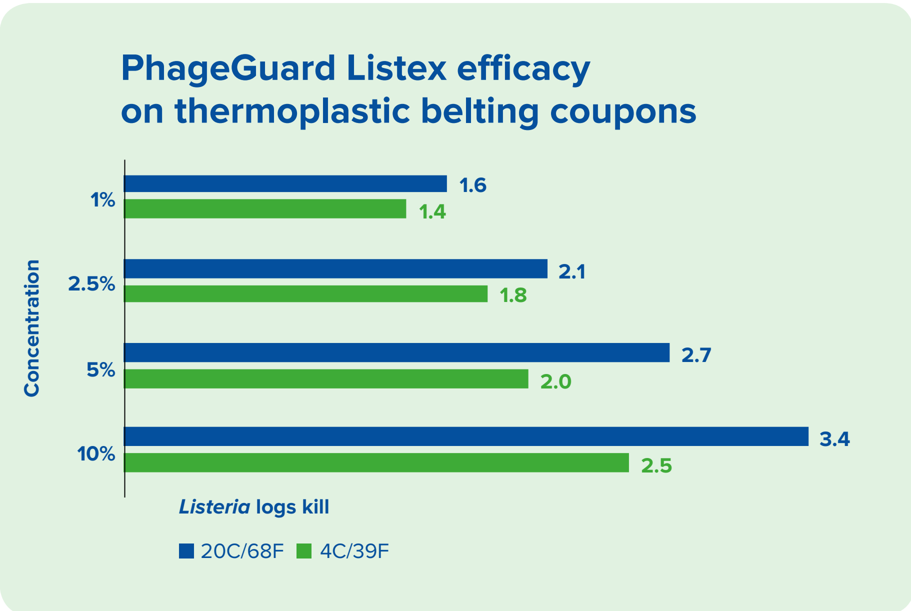
4.8.2 PhageGuard is more effective on *Listeria* Biofilms than Sanitation Chemicals

PhageGuard Listex outperforms common chemicals in the presence of food debris [30, 31]. This makes it sensible to use PhageGuard Listex as an additional and final spray on critical process equipment AFTER chemical cleaning and a water rinse.



4.8.3 PhageGuard eliminates *Listeria* on Food Contact Surfaces

Transporting belts are potential risk factors in cross contamination. Treating a conveyor belt with PhageGuard Listex is effective both on the belt showing 1.5-3 log reductions as well as on the product that is in contact with the belt with a 1.4 log reduction (internal data Micreos).



5 Conclusion and Application Recommendations

Pathogen risks in produce processing may originate on the farm, during transport and warehousing or in the processing plant. PhageGuard contributes to safer food production by using phages. As the natural enemy of bacteria, phages specifically kill pathogens like *Salmonella*, *Listeria* and *E. coli* O157 and leave the good ones intact. They are green, smart and easy to apply on food via spraying, misting or dipping. Phages can also be used directly on food contact surfaces or in the processing environment.

PhageGuard interventions on produce will depend on the area where the pathogen risks are originated and what processes and other interventions are used.
For on product use, PhageGuard products are applied as a surface intervention via spray, dip or enrober at a 1% concentration, resulting in

- 1-2 log reduction on various fresh and frozen fruits and vegetables
- No sensory effect on the treated food
- No impact on workers or equipment
- Compliance with organic production requirements

As a food contact surface spray, PhageGuard Listex helps prevent cross contamination. When used in the production environment, PhageGuard Listex should be considered a targeted additional step towards the eradication of hot spots and biofilms. Phages can be used during production to prevent real-time (cross-)contamination. If used as part of a sanitation scheme, practices have been completed and the area is well rinsed to remove any cleaning chemical residues as these are detrimental for the phages.

- Confirmed 3-5 log reduction on various surface types
- Phage will continue to work as long as the area is moist
- Phage can be used during production or during breaks on critical process equipment to decrease the risk of cross contamination.
- Phages penetrate into the biofilm

PhageGuard can reduce pathogen risks in produce processing. We will gladly help you determine where in your specific process PhageGuard can help you to make your product safer.

For more information on Phage Technology or PhageGuard products to eradicate foodborne pathogens, please contact Micreos Food Safety at sales@micreos.com or visit our web site at www.phageguard.com

References

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