



How phages reduce *Salmonella* in raw poultry processing

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Power of bacteriophages

Nature's force for balancing bacteria

Bacteriophages (or phages) are biological entities that serve to maintain the natural balance of bacterial populations. Every 48 hours, phages can reduce half of the world's bacterial population. This effect is due to their immense abundance. Phages are everywhere and outnumber bacteria by a factor of 10, making them the most common microorganisms on our planet. For reference: 1 ml seawater contains 1 billion phages.

The unique ability of phages

Similar to bacteria, phages are extremely diverse, with each phage having the unique ability to target a specific bacterial species down to the level of bacterial strains. This also includes food pathogens encountered in the food industry.

Phages: the future of food safety

Since 2005, Phageguard focused on developing phage solutions that specifically target *Salmonella*, *Listeria*, and pathogenic *E. coli*. Our precision-targeted phage products enable customers to achieve optimal pathogen control, without altering the organoleptic properties of treated foods or compromising natural/organic processing standards.

Phageguard S

The power of anti *Salmonella* phages

PGS

Designed for the food industry to control *Salmonella* and reduce the risk of cross-contamination in production settings, Phageguard S (PGS) enhances the unique ability of phages to provide natural control of all prevalent *Salmonella* serotypes in poultry, without compromising sensory attributes or introducing hazardous substances to the facility. As a result, PGS acts as a modern shield, improving the food safety of your poultry products while maintaining the integrity of your brand.



Effective against all prevalent *Salmonella* serotypes



Organic-listed and clean-label



Non-hazardous (harmless to humans, animals, and plants)



No wastewater pretreatment required



Specifically targets *Salmonella* and therefore has no impact on the color, taste, texture, or odor of the final product



Non-corrosive



Can be applied after applying chemicals (e.g., PAA, Chlorine) to contribute to a multi-hurdle, multi-technology approach

Developed for large-scale processing

PGS 5c

Phageguard S 5c (PGS 5c) enables *Salmonella* control in high-volume production lines while carrying the same approvals and certifications as PGS. Furthermore, PGS 5c contains the same phage formulation, providing identical efficacy, but with a fivefold increase in concentration. As a result, Phageguard S 5c offers a cost-efficient solution for high-volume use, enabling poultry processors to economically leverage the advantages of our anti *Salmonella* phage technology across large-scale operations.

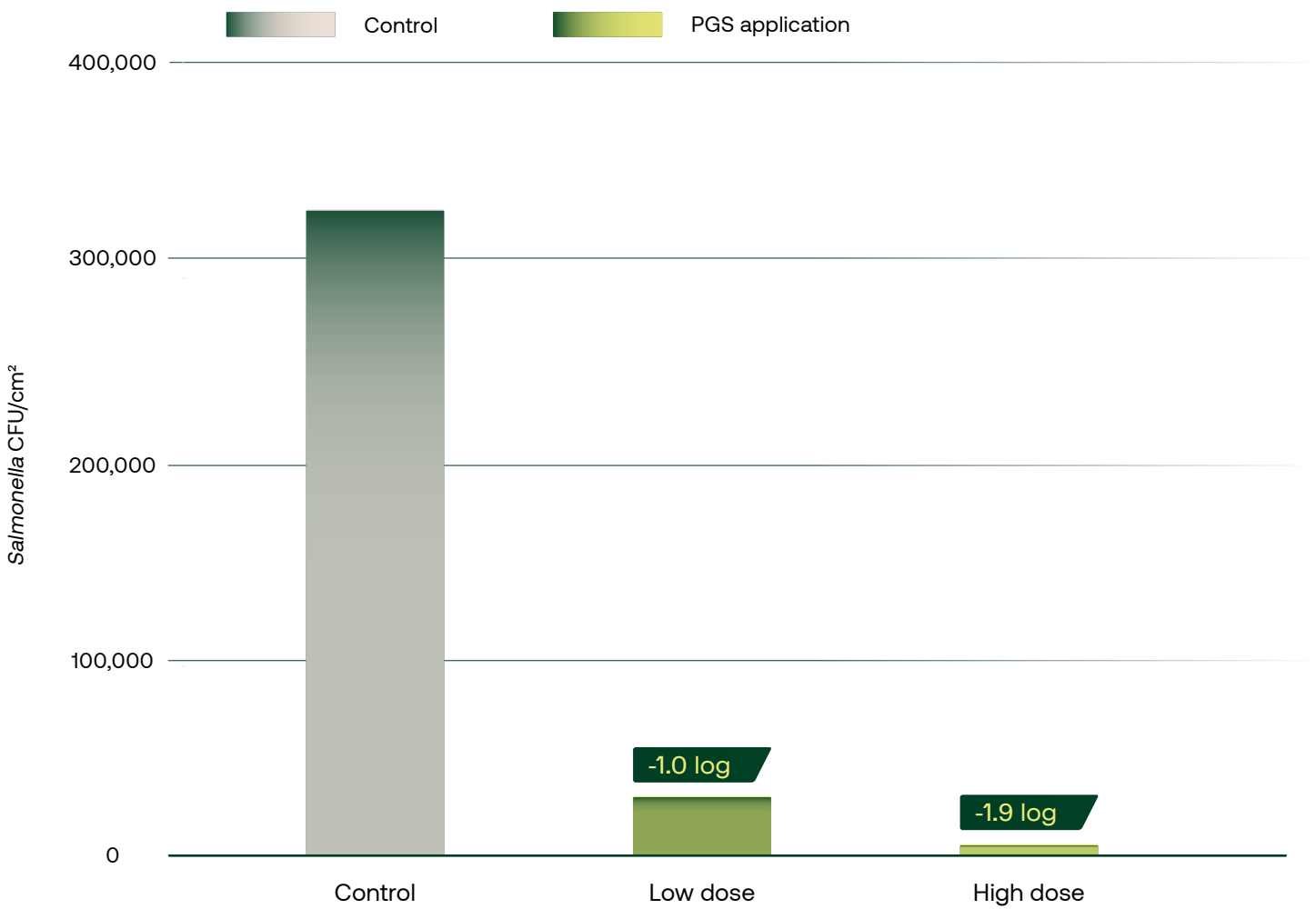
Ground poultry

Reducing *Salmonella* in ground chicken

Phageguard S (PGS) was applied at both low and higher dose levels. Depending on the dosage, PGS delivered *Salmonella* reductions ranging from 1.0 to 1.9 log. The control consisted of tap water measured over the same time span as the treated samples.

1.9 log
Reduction

A higher dose of PGS reduced *Salmonella* in ground chicken by up to 1.9 log. The achieved reductions were measured 24 hours post-application.



Poultry parts

Reducing *Salmonella* in a variety of poultry parts

Prior to the industrial trial, lab studies were performed on a variety of poultry parts, including giblets and livers, demonstrating >1 log reductions of *Salmonella* within 24 hours post-application. The industrial trials showed clear differences in *Salmonella*-positive samples between treated and non-treated product, as reflected in the results presented below:

-94%
Positives

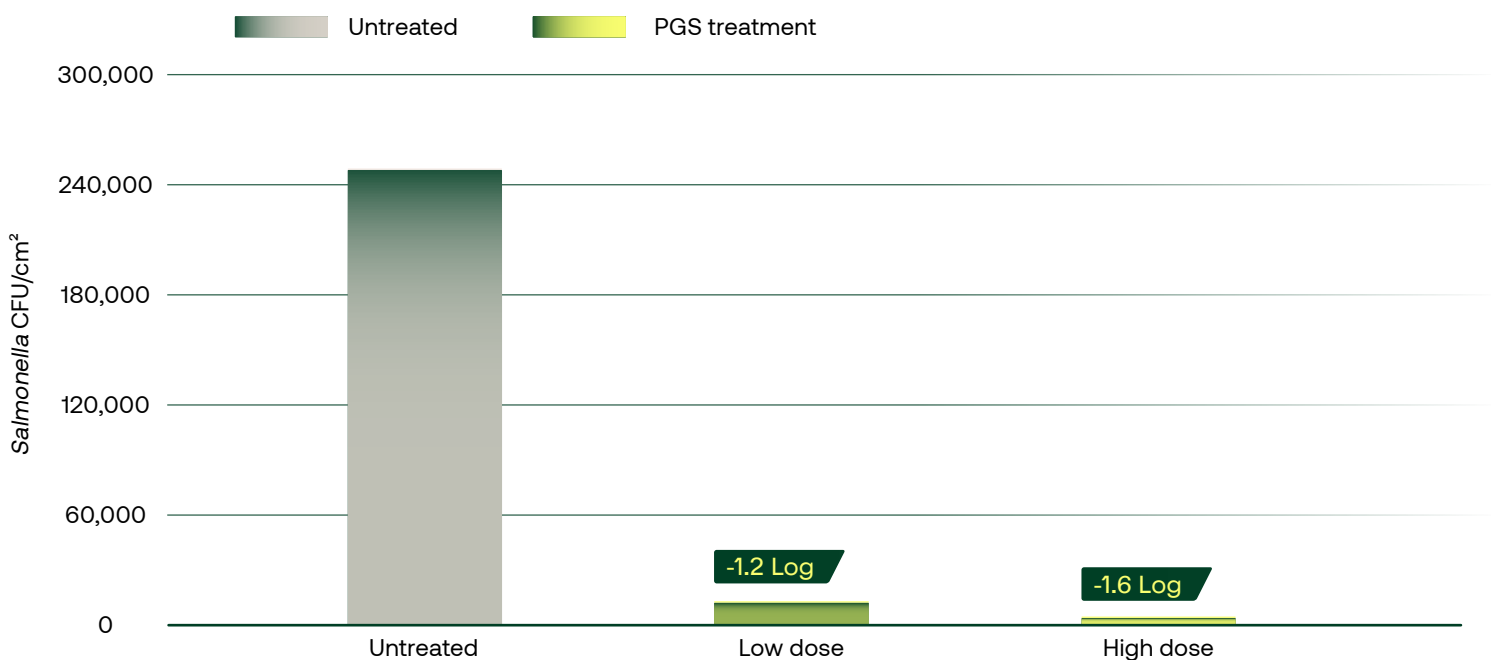
In total, **19/90** untreated chicken livers tested positive for *Salmonella*, compared to **1/90** livers treated with a single PGS application.

-88%
Positives

In total, **37/37** untreated turkey backs tested positive for *Salmonella*, compared to **8/37** turkey backs treated with a single PGS application.

1.6 log
Reduction

In the lab trial, PGS was applied at both low and higher dose levels to the chicken breast. Depending on the dosage, PGS delivered *Salmonella* reductions ranging from 1.2 to 1.6 log. The control consisted of tap water measured over the same time span.



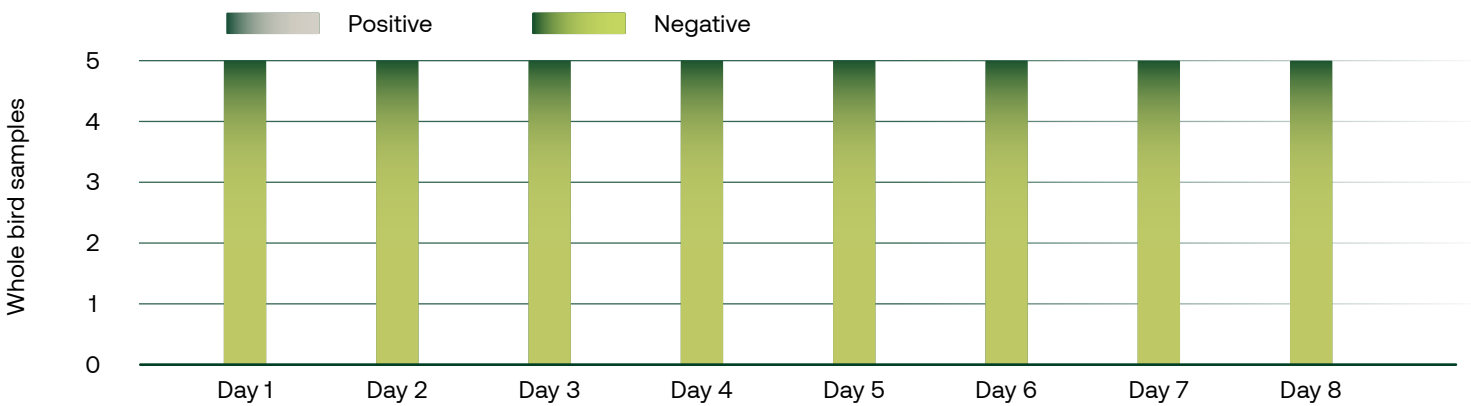
Whole bird carcasses

Reducing *Salmonella* on chicken carcasses

An industrial trial was conducted to evaluate the efficacy of Phageguard S (PGS) in reducing *Salmonella* on chicken carcasses using an ESS spray cabinet system. The trial included two setups: one applying a low PGS dose and the other a medium dose to determine the level required to achieve the desired reductions. Prior to PGS application, all carcasses received a PAA dip as part of a multi-hurdle approach. During the trial, approximately 200,000 lbs of chicken carcasses were treated daily.

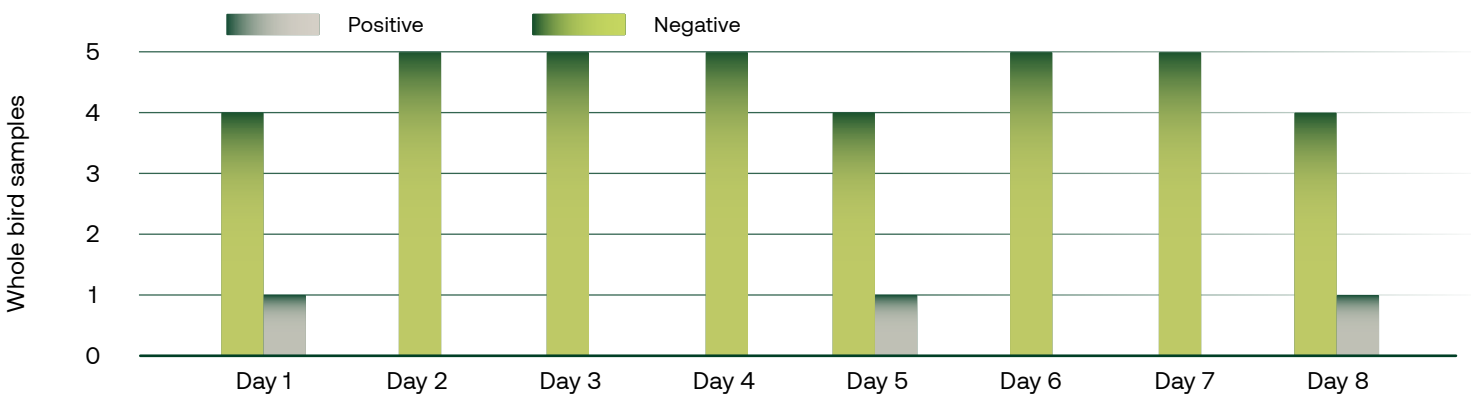
0%
Positives

PGS, applied at a medium dose following PAA treatment, demonstrated high efficacy against *Salmonella* on chicken carcasses. Over the 8-day trial, **0/40** samples tested positive.



7.5%
Positives

Using the same setup but with a lower PGS dose provided effective control, with several days showing no *Salmonella*-positive samples. In total, PGS combined with PAA resulted in only **3/40** positives detected.



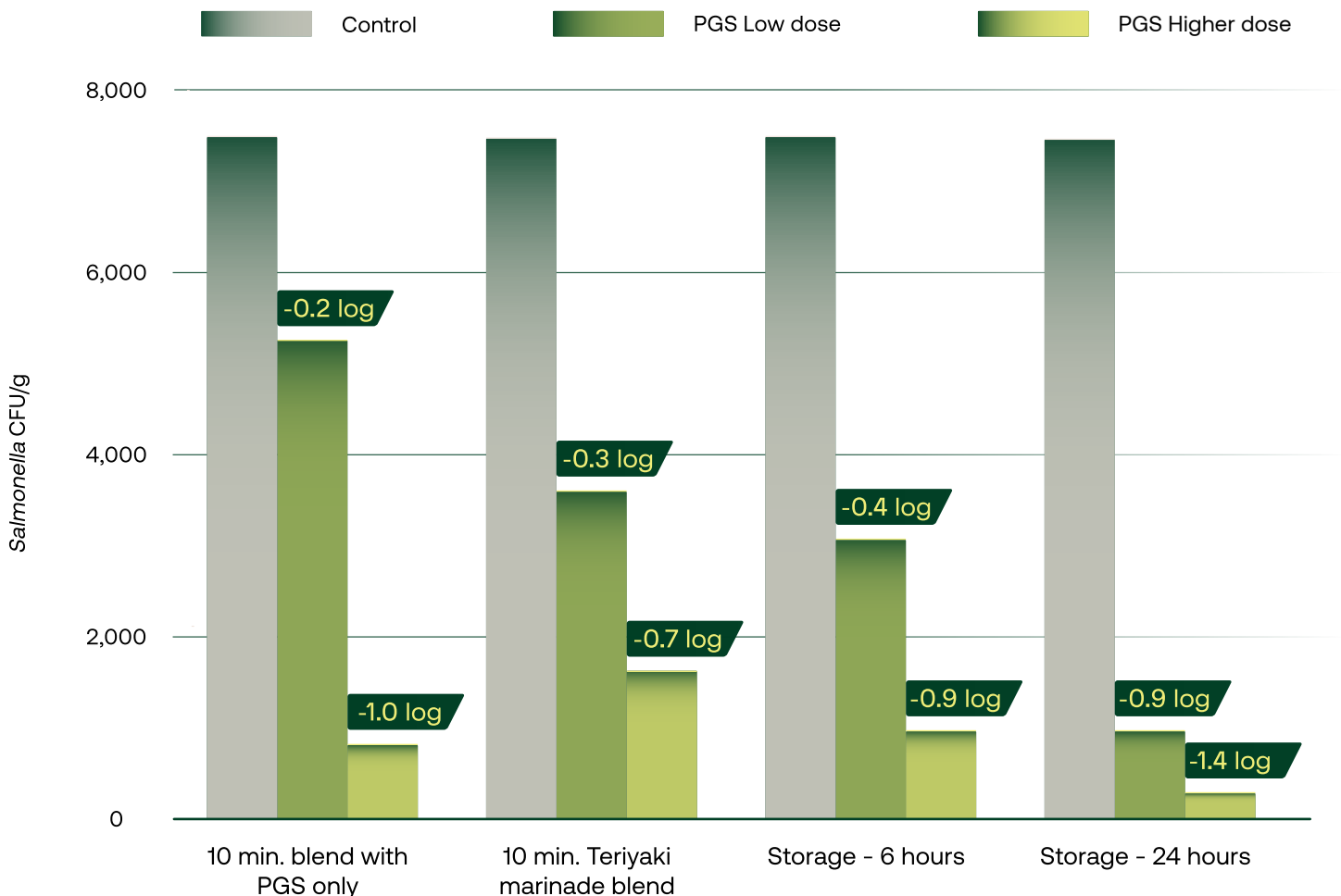
Marinated poultry

Reducing *Salmonella* in marinated chicken

To assess the performance of Phageguard S (PGS) for controlling *Salmonella* in marinated poultry processing, chicken thighs were treated with both a low and higher doses of PGS. After phage treatment, the processor's Teriyaki marinade was added and the product was tumbled for ten minutes. Depending on the dose applied, PGS achieved up to a 1.4 log reduction on the final marinated chicken thighs.

1.4 log
Reduction

A higher dose of PGS reduced *Salmonella* in the marinated chicken by up to 1.4 log. Reductions were measured after each tumbling step, as well as after 6 hours and 24 hours of storage.



Application

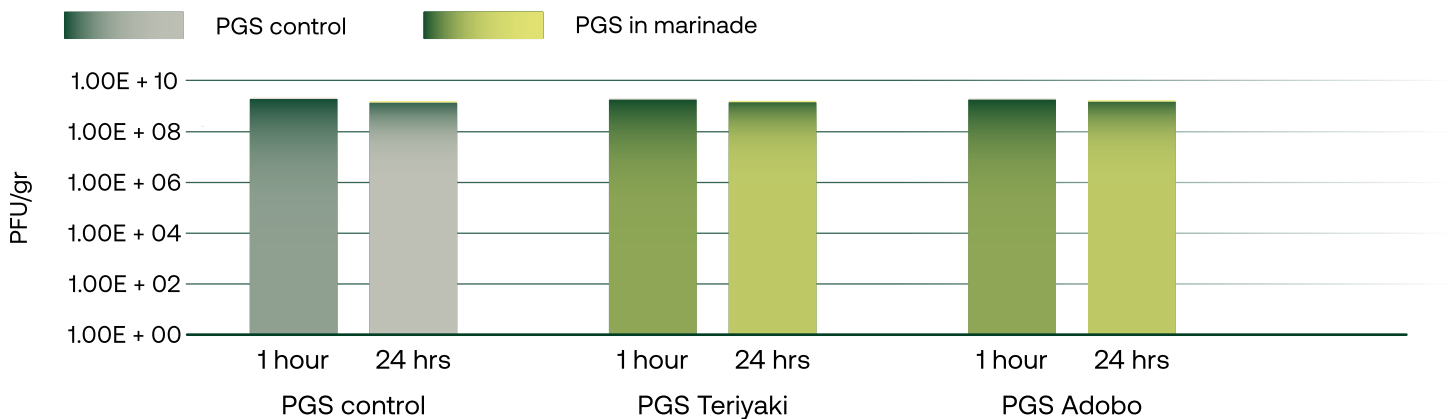
Versatility of PGS for application in poultry processing

Multiple application possibilities are available for PGS in poultry processing without requiring significant changes to the production setting. Depending on the application point and type of poultry product, a range of application techniques can be considered. Examples of how PGS can be implemented in facilities processing poultry are shown below:



Stability of PGS in marinades for effective control of *Salmonella*

Phage stability is directly linked to the efficacy of PGS against *Salmonella* in marinated chicken. To assess stability, PGS was added to Teriyaki and Adobo marinades obtained from a commercial processor of marinated poultry. Phage titers were measured at 1 hour and 24 hours. The results show that PGS concentrations remained stable for at least 24 hours in both marinades. The control consisted of PGS diluted in chlorine-free tap water at the same dose used for the marinade treatments.



Compliance

Trusted by government institutes around the globe

PGS has received approvals from government agencies around the globe and has been GRAS affirmed by the FDA since 2013. Furthermore, PGS and PGS 5c are OMRI-organic listed, produced in an FSSC 22000 certified facility, and both halal and kosher certified to ensure alignment with a broad range of poultry processors.

- ✓ USA, FDA GRAS (GRN 468) - 2013
 - ✓ Also applies to PGS 5c
- ✓ USA, USDA approved processing aid (Directive 7120.1) – 2016
 - ✓ Also applies to PGS 5c
- ✓ Canada, Health Canada: Processing aid – 2016
- ✓ Australia / New Zealand, FSANZ processing aid - 2012
- ✓ Israel, Food Control Services Ministry of Health: approved processing aid – 2014
- ✓ India, FSSI: Food contact surfaces and processing aid - 2021
- ✓ Chile, Undersecretary of Public Health (MINSAL) (ORD. B34/N794) - 2022
- ✓ Egypt, National Authority of Food Safety Egypt: Approved use in poultry production - 2023
- ✓ Dubai, DM Food Safety Department - 2025
- ✓ Costa Rica, Ministry of Health of the Government of Costa Rica - 2026



Partnerships

Collaborations with universities and research institutes

Phageguard has collaborated with numerous universities and research institutes to build a strong scientific foundation supporting our applied phage technology for controlling food pathogens. Published studies over the years demonstrate its effectiveness, versatile application across various food products, and compatibility with other food safety interventions in multi-hurdle approaches commonly used in industry.



The Americas

University of Nevada | Mississippi State University | California Polytechnic State University | Cornell University | University of Connecticut | University of Maryland | University of Wisconsin-Madison | Oregon State University | Food Science Institute | McMaster University | Aemtek | Instituto Tecnológico de Querétaro | Universidade Federal da Bahia



Europe

WUR Wageningen University | ETH Zürich | University of Ghent | Utrecht University | Institut Pasteur | Insitut du Porc | Nofima | TNO | Universidad D Cordoba | Universitat de Lleida | Radboud University | Max Ruber Institute | BfR Institute for Risk Assessment | Quadram Institute | Food Valley | Aristotle University of Thessaloniki | Universtat de Lleida | Nizo | IFIP | CEBAS | CSIC | ISS | RCT Gelderland | Oost NL | Han University of Applied Sciences | Saxion Hogeschool | DIL | KU Leuven

Supporting the industry

Study cases and industrial implementations

The following overview presents the poultry sectors in which Phageguard currently supports the industry, as well as the R&D projects that further explore the versatility of phage implementation to expand our services.

PGS Industrial implementations - Postharvest *Salmonella* control

Ground poultry

Poultry parts

Whole bird carcasses

Marinated poultry

Hard-cooked eggs

PGS Research & Development projects - Preharvest *Salmonella* control

Live broilers

Hatchery eggs

PGL Industrial implementations - *Listeria* control

Ready-to-eat poultry

Hard-cooked eggs

Production surfaces



Phage technology
Salmonella control

Applied phage technology to control food pathogens



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