FOOD SAFETY

พลิกเกมความปลอดภัยอาหารด้วยเทคโนโลยีการควบคุมเชื้อจุลินทรีย์ก่อโรคแบบครบวงจร

LAB SAFETY EDITION
SMART LABS. SAFE FOOD. STRONG GROWTH.
Food Focus Thailand 2026 PRO SERIES
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Key Foodborne Pathogens & Technologies for Controlling Contamination

Innovations for Safer Food Production

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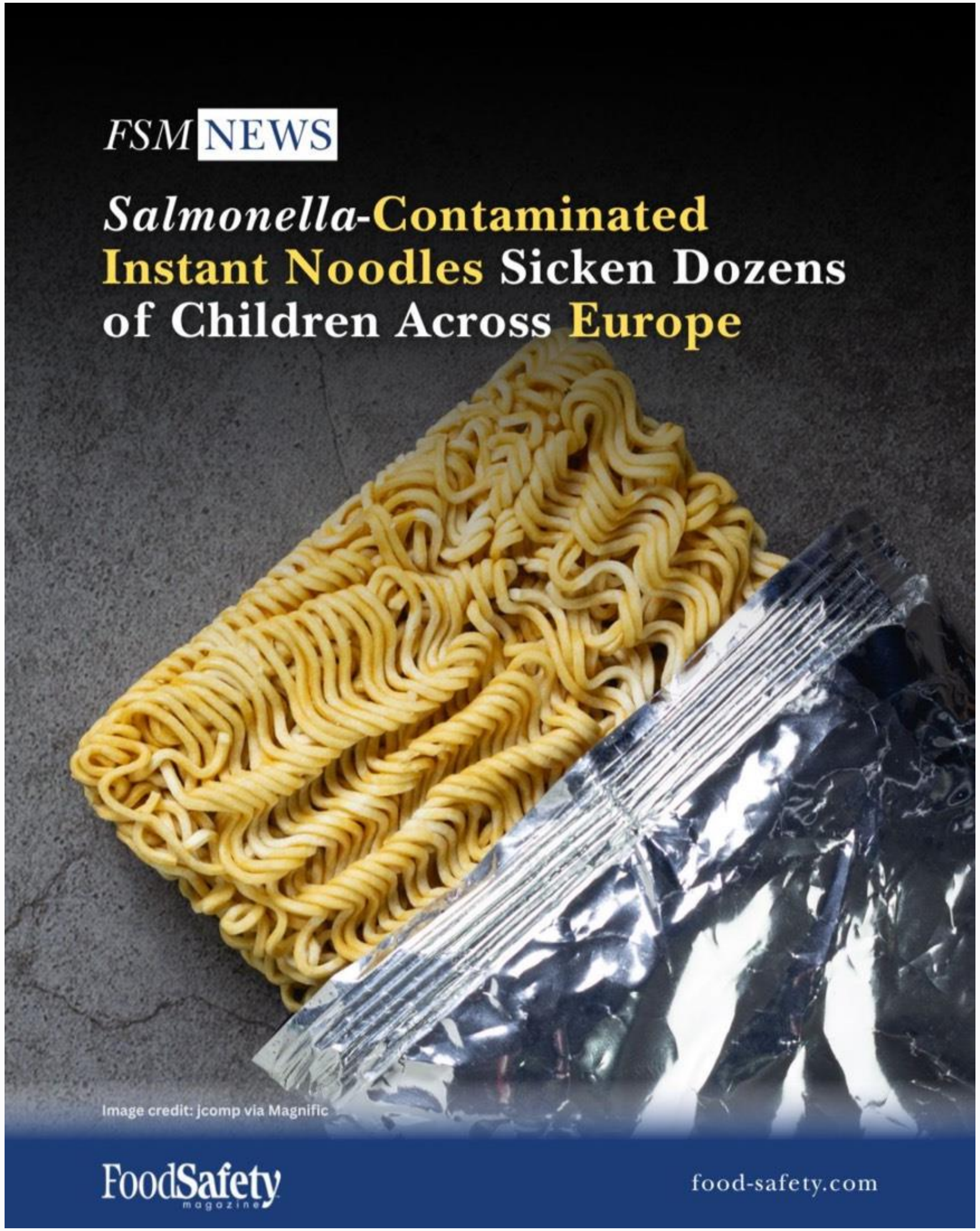
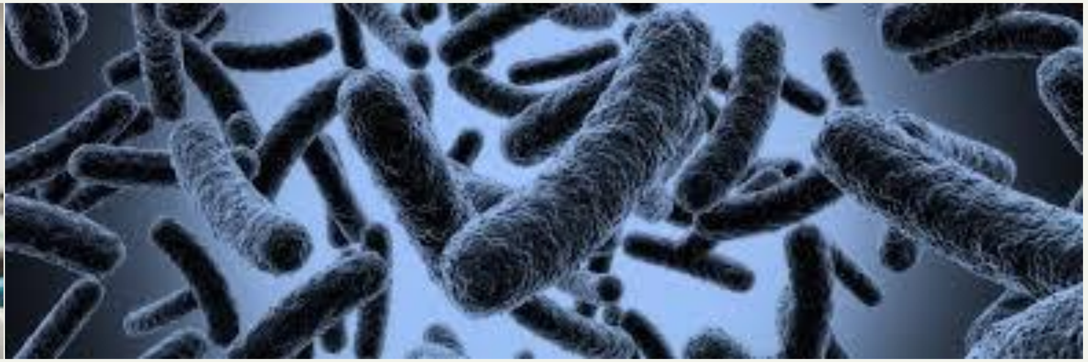
Recent Food Recall Cases




WHY IT MATTERS
TO THE FOOD INDUSTRY
Protect consumers
and public health
Prevent disruptions
in the food supply chain
Avoid financial losses
and regulatory penalties
Build trust and strengthen
brand reputation

Topics

1. ภาพรวม: ระบบแจ้งเตือนอย่างรวดเร็วสำหรับอาหารและอาหารสัตว์ - Rapid Alert Systems for food and feed

2. เชื้อก่อโรคในอาหารที่น่ากังวลต่อความปลอดภัยของอาหารและความเสี่ยงด้านสาธารณสุข: *Salmonella* และ *Listeria monocytogenes*

3. เทคโนโลยีหลักในการควบคุมการปนเปื้อนของเชื้อก่อโรคในกระบวนการแปรรูปอาหาร

Food Contamination – Food hazards

3 types of hazards associated with foodborne illnesses:

Hazard	**Examples**
Biological	▪ Bacteria (*Listeria monocytogenes*, *Salmonella*, etc.) ▪ Parasites (*Cryptospordium*, *Toxoplasma gondii*, etc.) ▪ Viruses (hepatitis A, Norovirus, etc.) ▪ Toxins (mycotoxins – fungal contamination)
Chemical	▪ Cleaners and sanitizers ▪ Lubricants ▪ Antibiotics ▪ Hormones
Physical	▪ Glass ▪ Woods ▪ Metal

ความปลอดภัยอาหาร: ปัญหาที่ไม่ควรมองข้าม

WHY FOODBORNE PATHOGENS STILL MATTER

A Persistent Threat to People, Business and the Global Food System

Despite advances in science and technology, foodborne diseases remain one of the world's most common – yet most preventable – public health problems.

CDC (U.S.)

Centers for Disease Control and Prevention

THE BURDEN IN THE UNITED STATES (CDC, 2024*)

48 MILLION
Estimated illnesses
(1 in 6 Americans)

128,000
Hospitalizations

3,000
Deaths

$17.2 BILLION
Estimated annual cost
(medical care + productivity losses + premature deaths)

Source: CDC. Estimated Foodborne Illness in the United States. CDC 2024 (Data updated March 2024)
https://www.cdc.gov/foodborneburden

THE GLOBAL PICTURE (WHO)

World Health Organization

Foodborne diseases are a global public health challenge.

~600 MILLION
People fall ill every year
(almost 1 in 10 people worldwide)

~420,000
Deaths every year

~US$ 110 BILLION
Lost in productivity and medical expenses annually

Source: WHO. Estimates of the global burden of foodborne diseases. WHO 2015.
https://www.who.int/publications/i/item/9789241565165

WHY IT STILL MATTERS

High impact on public health
Causes severe illness and death, especially in children, elderly, and immunocompromised people.

Huge economic burden
Drives up healthcare costs, product recalls, insurance, and trade losses.

Globalized food supply
Pathogens can spread rapidly across borders within hours.

Consumer trust & brand reputation
One incident can damage brand equity built over years.

Sustainability & One Health
Safe food supports healthy people, healthy animals, and a healthy planet.

FOOD RECALLS: A GROWING CONCERN

Recent global recalls highlight the impact of pathogen contamination on consumers and brands.

Thousands of food products are recalled every year due to pathogen contamination.

RECALLS COST COMPANIES MORE THAN JUST MONEY:

- ✓ Brand damage
- ✓ Loss of consumer trust
- ✓ Operational disruption
- ✓ Regulatory action & fines
- ✓ Lost sales and market share

EXAMPLES OF RECENT RECALLS

Boar's Head Listeria Outbreak (USA, 2024)

> 60 deaths hundreds of illnesses

Ready-to-eat meat products contaminated with *Listeria monocytogenes*

Dole Packaged Salad Recall (USA, 2023)

Multiple products recalled in 25 states

Contaminated with *Listeria monocytogenes*

Frozen Waffles Recall (USA, 2024)

> 10,000 cases recalled

Possible contamination with *Listeria monocytogenes*

Salmonella in Chocolate Products Europe, 2022–2023

Several products recalled across multiple countries

Salmonella contamination in chocolate products

STEC in Leafy Greens Europe, 2022

Outbreaks linked to multi-country cases

Shiga toxin-producing *E. coli* (STEC) detected

Recalls are preventable.

Investing in prevention protects people, brands and business sustainability.

People With a Higher Risk of Foodborne Illnesses

People who are more likely to get ill from eating food contaminated with pathogens

Adults aged 65 and older

Children younger than 5 years

People with weakened immune systems

Pregnant women

Rapid Alert System for Food and Feed

In 2023, EU reported

#1 Salmonella

#2 Listeria monocytogenes

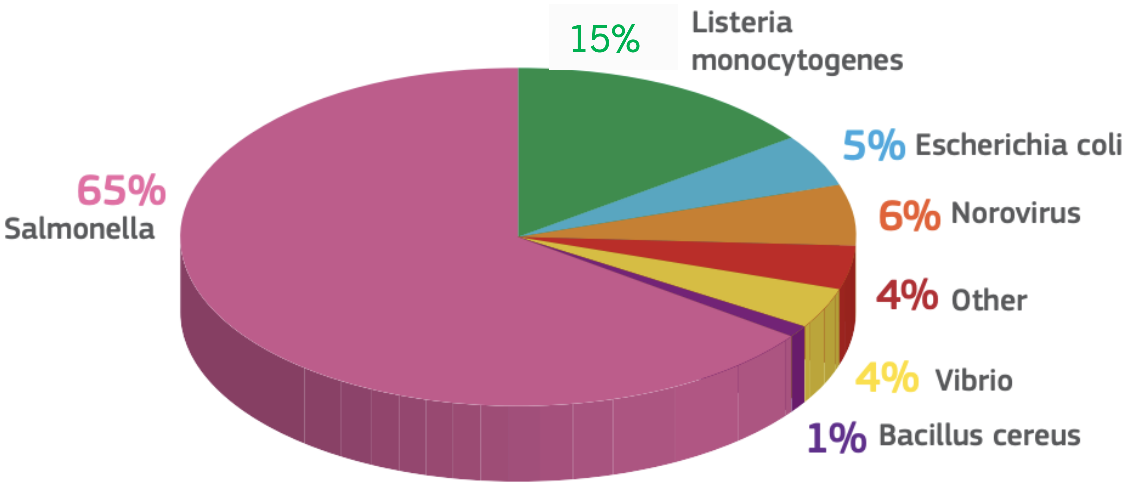
-leading cause of food contamination

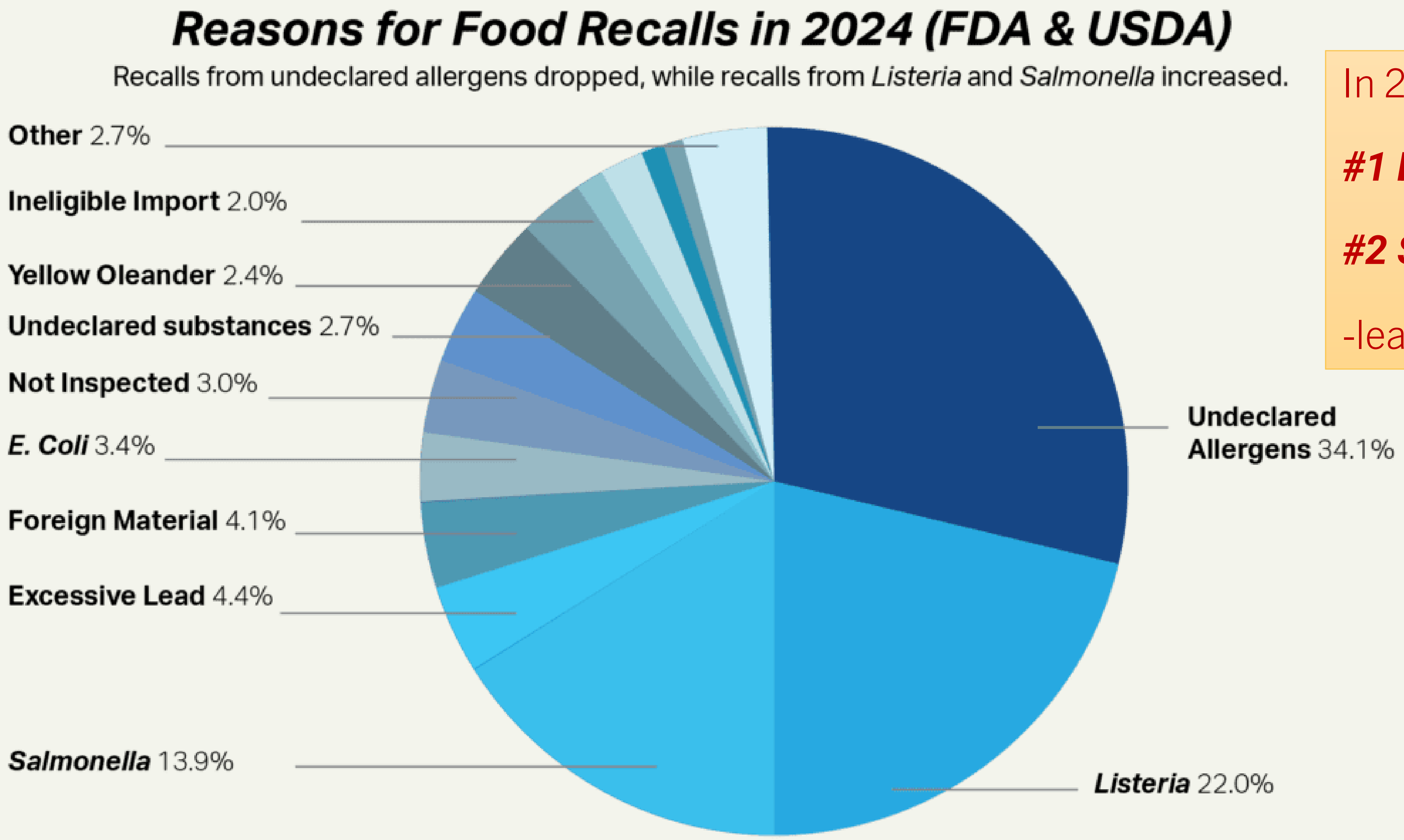
3.1.3. Pathogenic microorganisms

During 2023, pathogenic microorganisms were the second most common hazard category in food (856 notifications). The most reported food categories continued to be poultry meat and poultry meat products (316) and nuts, nut products and seeds (93).

Following the same trend as in 2022, *Salmonella* was the most frequent pathogenic microorganism (582 notifications; **Figure 7**), followed by *Listeria monocytogenes* (131), *Escherichia coli* (50) and noroviruses (50), all primarily detected in products of animal origin. Notably, 153 *Salmonella* notifications concerned poultry meat and poultry meat products from Poland. This issue is further discussed in section 3.5.2 of the report.

Figure 7: RASFF notifications on pathogenic microorganisms in food





In 2024, FDA/USDA reported

#1 Listeria monocytogenes

#2 Salmonella

-leading cause of food contamination

https://fsns.com/food-recalls-in-2024-revealing-the-statistics/

Food Control

Volume 129, November 2021, 108243

Microbiological hazards associated with food products imported from the Asia-Pacific region based on analysis of the rapid alert system for food and feed (RASFF) notifications

Ayokunle Christopher Dada [a], Yinka M. Somorin [b], Collins N. Ateba [c], Helen Onyeaka [d], Amarachukwu Anyogu [e], Nor Azman Kasan [f], Olumide A. Odeyemi [g]

Table 4

RASFF notifications of pathogenic microorganisms in food originating from the Asia-Pacific Region (n = 1873) from 2000 to 2020 based on originating country.

	Country of origin										
Pathogen genus	India	Thailand	Vietnam	Bangladesh	China	Malaysia	Indonesia	Laos	ANZ	Others	Grand Total (%)
Salmonella	551	411	182	165	69	30	38	30	23	61	1560 (73.55%)
Vibrio	61	40	59	35	12	62	31	0	1	8	309 (14.57%
Bacillus	16	5	14	2	42	0	3	0	0	10	92 (4.34%)
Escherichia	3	16	5	0	2	4	0	15	0	2	47 (2.22%)
Norovirus	0	0	30	0	11	0	0	0	0	1	42 (1.98%)
Not specified	6	2	5	0	4	0	0	0	0	11	28 (1.32%)
Clostridium	3	5	2	0	12	0	0	0	0	0	22 (1.04%)
Campylobacter	0	5	1	0	0	0	0	0	0	0	6 (0.28%)
Staphylococcus	0	1	2	0	0	0	0	0	0	0	3 (0.14%)
Enterococcus	1	0	0	0	0	0	1	0	0	0	2 (0.09%)
Hepatitis	0	0	0	0	1	0	0	0	1	0	2 (0.09%)
Pseudomonas	1	0	0	0	0	0	0	0	0	1	2 (0.09%)
Cronobacter	0	0	0	0	1	0	0	0	0	0	1 (0.05%)
Fungi	0	0	0	0	1	0	0	0	0	0	1 (0.05%)
Plesiomonas	0	0	0	0	0	0	1	0	0	0	1 (0.05%)
Shigella	0	1	0	0	0	0	0	0	0	0	1 (0.05%)
Yersinia	0	1	0	0	0	0	0	0	0	0	1 (0.05%)
Streptococci	0	0	0	0	1	0	0	0	0	0	1 (0.05%)

Other_N: Other notifying countries: Cyprus, Austria, Slovenia, Ireland, Lithuania, Iceland, Romania, Switzerland, Bulgaria, Croatia, Estonia, Hungary, Latvia, Luxembourg, Slovakia, Sri Lanka. Other_O: Other originating countries: Australia, Cambodia, New Zealand, Pakistan, Philippines, Hong Kong, Taiwan, Singapore, South Korea, Afghanistan, Nepal.

The total number of pathogens (n = 2119) exceeds the total number of notifications (n = 1873) because of the co-occurrence of pathogens.

In 2000-2020, RASFF reported

#1 Salmonella

-leading cause of food contamination among food product originating from APAC region

Key Foodborne Pathogens

Salmonella

- Common in poultry, eggs, meat, dairy, and produce
- Causes fever, diarrhea, abdominal cramps

Sources

Listeria monocytogenes

- Found in ready-to-eat foods, dairy, seafood, and vegetables
- Causes listeriosis; severe inpregnant women, newborns, and immunocompromised

Sources

STEC / *Escherichia coli*

- Shiga toxin-producing E. coli
- Causes severe diarrhea, hemorrhagic colitis, HUS, kidney failure

Sources

Campylobacter

- Common in poultry, raw milk, and contaminated water
- Causes diarrhea, fever, abdominal pain

Sources

Vibrio spp.

- *Vibrio parahaemolyticus, V. vulnificus, V. cholerae*
- Causes gastroenteritis, septicemia, wound infections

Sources

Sources: WHO (2022); FAO (2021); CDC (2023); EFSA (2023)

Key Foodborne Pathogens by Food Sector

Use this as a "risk map" for training: pathogens differ by sector, process, product pH/aw, and post-lethality handling

Meat & poultry

Raw animal inputs + slaughter/evisceration + post-lethality exposure

- *Salmonella*
- STEC
- *Listeria monocytogenes*

Processed RTE foods

No consumer kill step; biofilms and cold growth matter

- *Listeria monocytogenes*
- *Salmonella*
- STEC

Juice & drinks

Low pH helps but does not replace validated 5-log pathogen reduction

- *E. coli* O157/STEC
- *Salmonella*

Dairy

Raw milk, pasteurization control, post-pasteurization contamination

- *Listeria monocytogenes*
- *Salmonella*
- STEC

Training message: Recalls are usually caused by control failures at predictable points

References: CDC Current Outbreaks; WHO Food Safety Fact Sheet; EFSA/ECDC EU One Health Zoonoses Report 2024; FDA Juice HACCP Guidance.

KNOW THE PATHOGENS. CONTROL THE RISK. PROTECT PUBLIC HEALTH.

Priority Foodborne Pathogens at a Glance

ATHODGEN	KEY CHARACTERISTICS	ILLNESS / SYMPTOMS	HIGH-RISK FOODS
Salmonella	Gram-negative rod; survives in animals, environment and food	Fever, diarrhea, abdominal cramps, nausea, vomiting	Poultry, eggs, meat, dairy, produce, spices
Listeria monocytogenes	Psychrotrophic; grows at refrigeration temperatures; biofilm former	Fever, muscle aches, nausea; severe in pregnancy and immunocompromised	Ready-to-eat meats, soft cheeses, dairy, smoked seafood, pre-cut vegetables
STEC / *Escherichia coli*	Shiga toxin-producing strains; low infectious dose	Severe diarrhea, bloody stools, HUS, kidney failure	Undercooked beef, raw milk, leafy greens, sprouts, contaminated water
Campylobacter	Microaerophilic; sensitive to drying and heat	Diarrhea (often bloody), fever, abdominal pain	Poultry, raw milk, untreated water
Vibrio spp.	Halophilic; thrives in marine environments	Gastroenteritis, septicemia, wound infections	Seafood (raw/undercooked), coastal water


Sources of Contamination
People
Facilities
Raw materials
Other supplies
water
Equipment
Food
Animals
Pests
Environment

Pathogens Linked to Major Sources of Contamination

Staphylococcus aureus

Hepatitis A

From human

Salmonella spp.

Listeria spp. & LM

Bacillus cereus

E. coli O157/STEC

From raw materials / facilities / environment

Type of contamination

	Type of Contamination	Examples of Incidents in a Processing Plant
1	Direct contamination: transfer of human pathogens to food or food contact surface.	Employee working at RTE area did not wash hands properly.
2	Cross-contamination: transfer of pathogens from food or a surface to another food or food contact surface.	• Shovel for scooping raw meat was used to handle processed product. • A tube brush for cleaning drains was found on a cookie conveyor. • A white tub trolley for handling rejects was used to store cooked macaroni.
3	Cross-contact: unintentional incorporation of a food allergen into another food through accidental transfer.	• Paddle for stirring wheat dough was swapped with that for soy. Wheat product labels did not list soy. • A red scoop for handling milk powder is cleaned and sanitized before handling soy, but some product was found on the surface after cleaning.

Salmonella in Poultry Production Chain

A Food Safety Concern in Poultry

***Salmonella* is a ubiquitous pathogen that linked to multiple sources from pre-harvest to post-harvest.**

- It typically colonizes in the **GI tract** of chickens
- **Food safety concern** - *Salmonella* is primarily transmitted through contaminated poultry products:
  - Poultry serves as the main reservoir for various non-typhoidal *Salmonella* (NTS) serotypes among food-producing animals
  - S. Enteritidis, and S. Typhimurium, belonging to the NTS, is responsible for the majority of human salmonellosis

Salmonella Contamination in Poultry Production Chain

- **The most common serovars identified in foodborne outbreak cases include Enteritidis, Newport, Typhimurium, Javiana, 4,[5],12:i:-, Oranienburg, and Infantis** (Collins et al., 2022)
- *Salmonella* serotypes found in poultry have continued to change:
  - Previous persistent: Heidelberg, then Kentucky now has emerged.

The Target Serovars

EU legislation (such as Regulation (EC) No 2160/2003) primarily focuses on the serovars most frequently linked to human disease. For poultry (*Gallus gallus* and turkeys), the mandated target serovars are:

***Salmonella* Enteritidis**

***Salmonella* Typhimurium**

***Salmonella* Infantis**

***Salmonella* Hadar**

***Salmonella* Virchow**

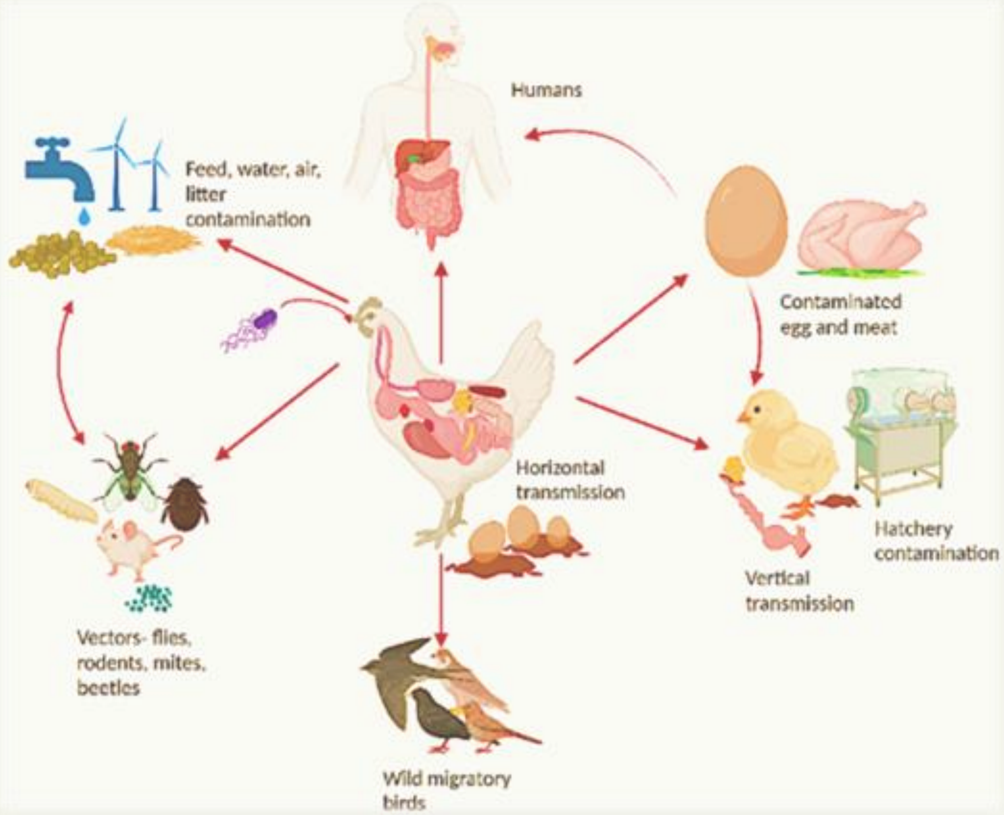
Salmonella Mitigation—Where Should We Begin?

Microbial contamination of the poultry carcasses can originate either from:

(1) **the external surfaces** of the birds such as the feathers and skin through feed/water/litter/rodents/environments - Birds' exterior surfaces can bring *Salmonella* & other microorganisms from the farm into processing facilities.

(2) **the internal gut contents (*Salmonella* got in** through hatchery (vertical transmission)/feed//rodents/environments) during evisceration process, resulting in cross-contamination of other carcasses.

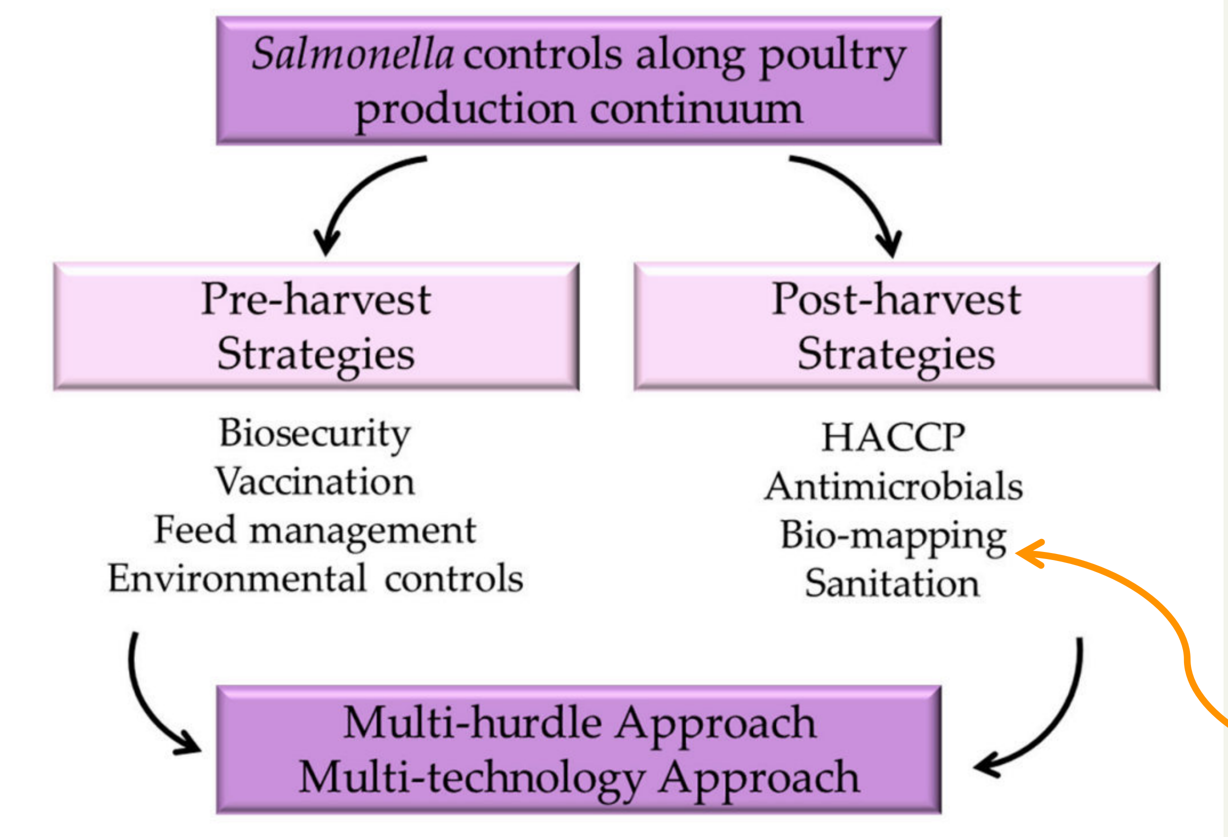
→ external or gastrointestinal sources of contamination of *Salmonella*



Shaji, S., Selvaraj, R. K., & Shanmugasundaram, R. (2023). *Salmonella* Infection in Poultry: A Review on the Pathogen and Control Strategies. *Microorganisms*.

Salmonella Mitigation—Where Should We Begin?

Strategies to control *Salmonella* in poultry production



Betiku, E.; Ogundipe, T.T.; Kalapala, T.; Obe, T. A Mini-Review on Multi-Hurdle Control of *Salmonella* Along Poultry Production Continuum. Animals 2025, 15, 875.

EMP to verify these

Salmonella Mitigation—Where Should We Begin?

Strategies to control *Salmonella* in poultry production

Live animals ❯ Slaughter ❯ Chilling ❯ Cutting / grinding ❯ Cooking ❯ Slicing / packing

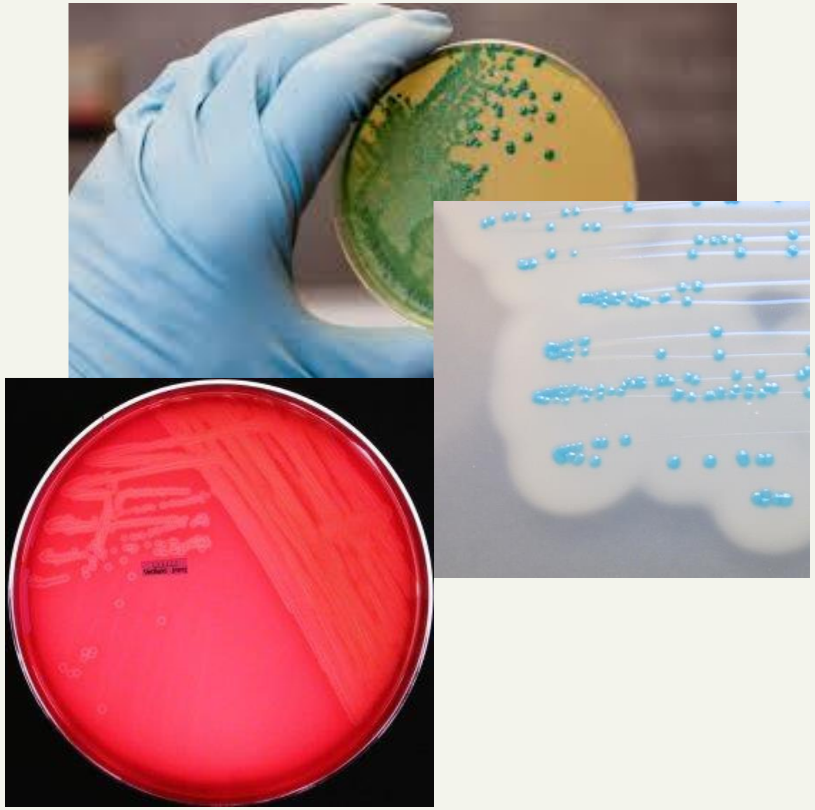
The integrators need to monitor food safety hazards – especially *Salmonella* prevalence – from live bird holding to evisceration, processing, packaging and shipping.

Antimicrobial interventions and applications strategically sequenced throughout the processing:

- Acidifiers in scald tanks
- Chlorine-based compounds or other formulated sprays after feather-picking / spraying or dipping following evisceration

Listeria monocytogenes(LM)

- Human cases of listeriosis are almost exclusively caused by *Listeria monocytogenes* – pathogenic species (β-Hemolytic, PI-PLC positive – virulence factor Phosphatidylinositol-specific phospholipase C)
- **Psychrotrophic:**
  - *LM* can grow over a wide range of temperatures, including refrigerated temp. (-0.4°C to 45°C). Optimum growth temperature is 37°C
  - pHs (4.6-9.5)
  - High salt concentrations (up to 20%). Can survive at a relatively low water activity ($a_W < 0.90$)
- 16 serotypes – with only 3 are associated with the majority of listeriosis cases: 1/2a, 1/2b, 4b



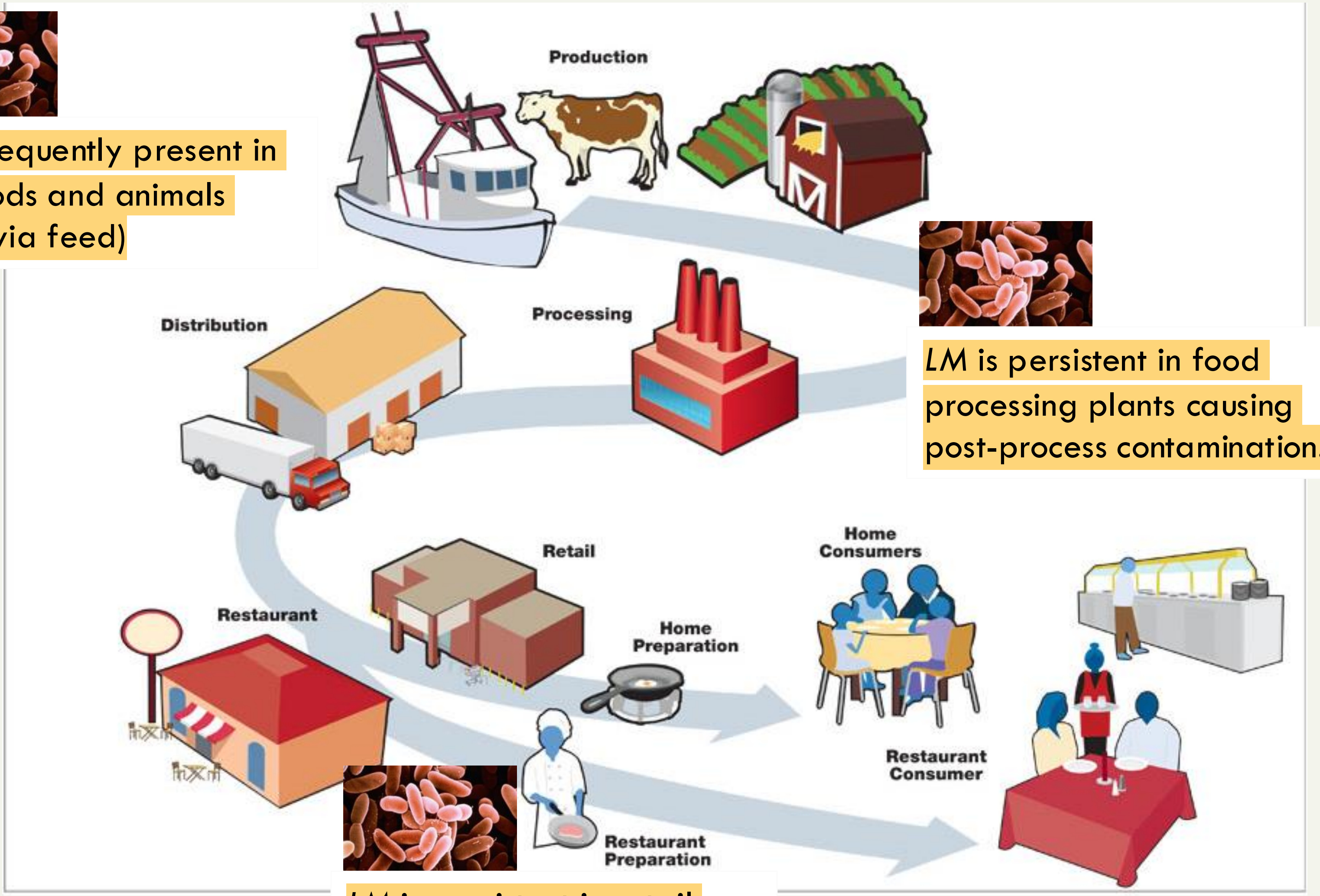
Where is *L. monocytogenes* Found?

- **A ubiquitous pathogen**: It is known to exist in a wide variety of environments
- **Natural & Agricultural Environments:** soil, water, feed, natural environments, and agricultural areas
- **Food Production System**

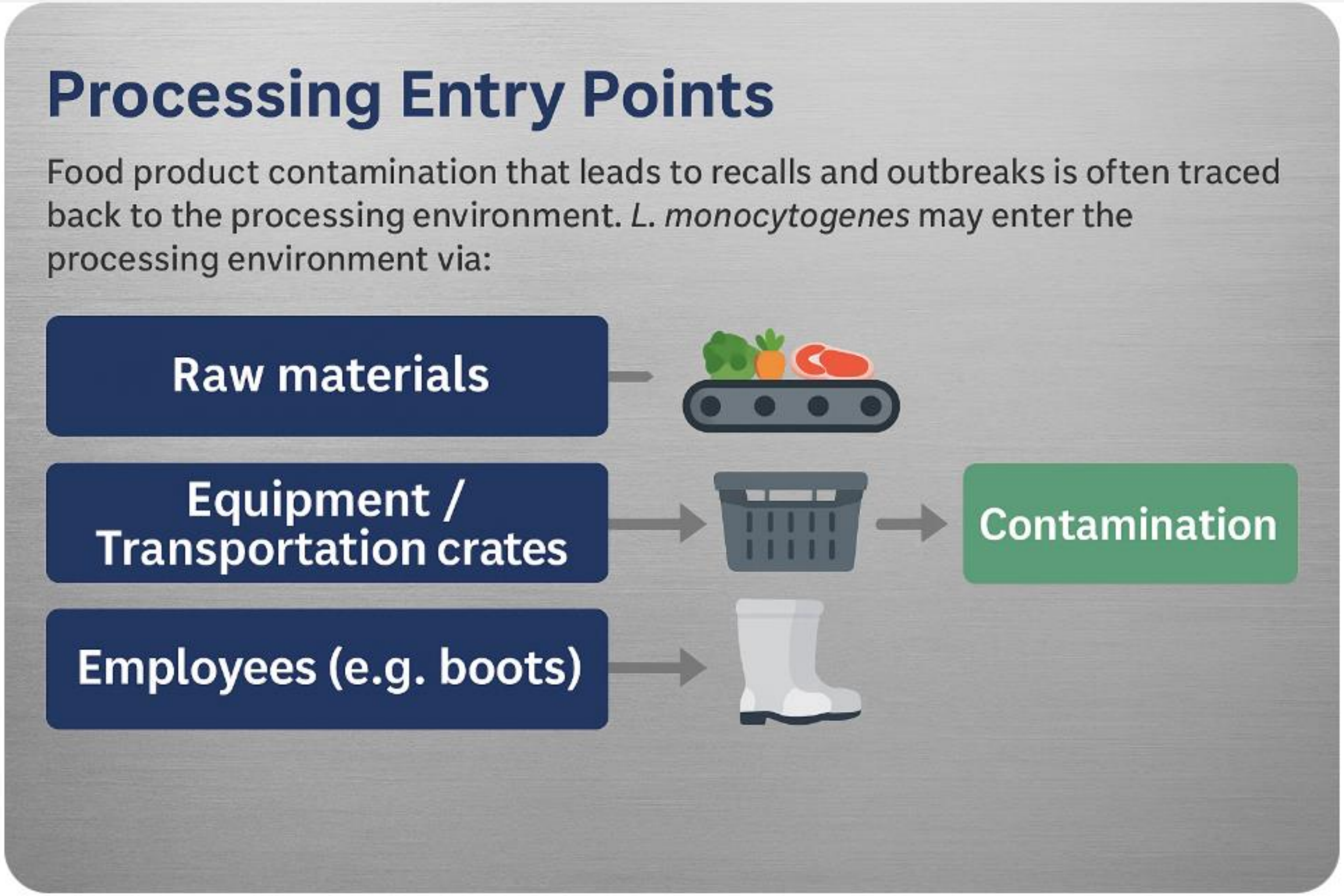
LM is frequently present in raw foods and animals origin (via feed)

LM is persistent in food processing plants causing post-process contamination.

LM is persistent in retail environments and household.



How can *L. monocytogenes* cause food product contamination ?



Challenges of *L. monocytogenes* in Food Processing Environment

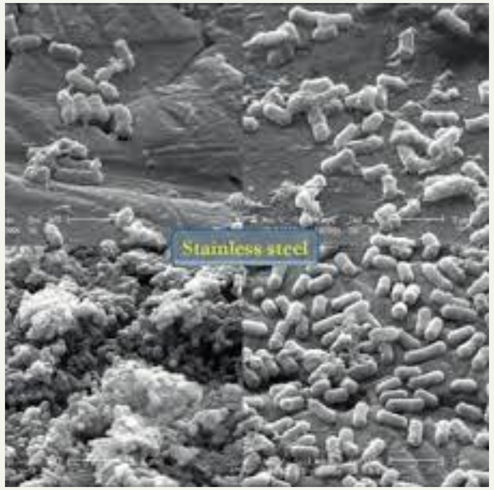
1. Niche Colonization: *Listeria* can inhabit and multiply in various niches (sites) within the facility, such as equipment crevices, refrigeration units, floor drains, condensate, and standing water

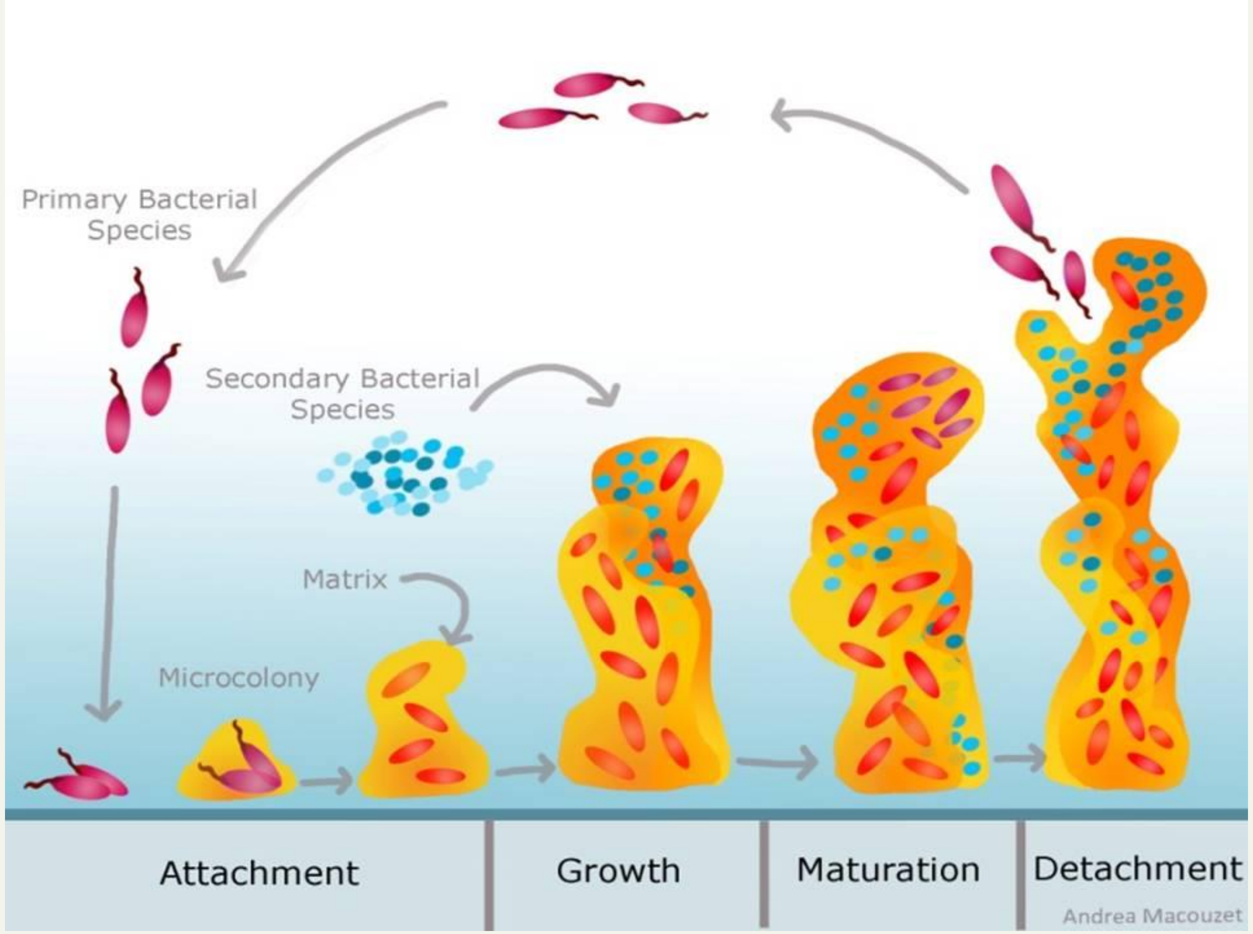
- Dripping condensate and high-pressure systems
- Cooler temperature equipment selection for *Listeria* growth or survival
- Hollow rollers on conveyers
- Space between close fitting parts
- Cracked seals and valves

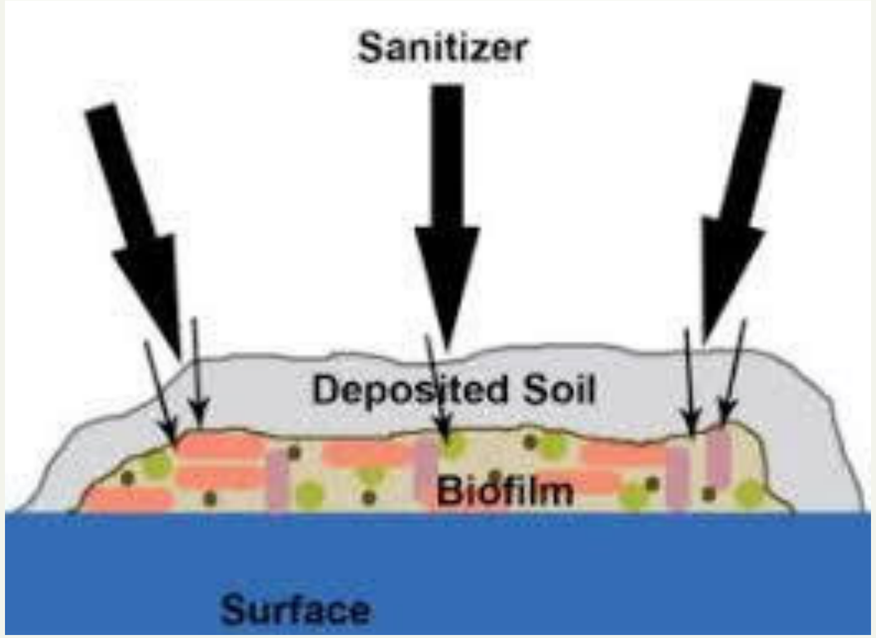
Biofilm of LM

Harborage and Protection

- Bacterial biofilms : **invisible, sticky layers** of bacterial cells enclosed in a self-produced polymer matrix (exopolysaccharides, proteins and nucleic acid) that are attached to a surface.
- Bacteria can adhere to cells and tissues as well as to solid surfaces (e.g. floor or equipment found at a farm, slaughterhouse, or processing plant).







Challenges of *L. monocytogenes* in Food Processing Environment

2. Poor equipment design that create niches where cleaners and sanitizers cannot reach allow *Listeria* to live for extended periods

- **Conveyor belts:** Can harbor *Listeria* in difficult-to-clean niches
- **Slicers:** Difficult to clean due to complex design

3. Lack of hygienic zoning: Improper separation of areas with different contamination risks (e.g., raw material receiving vs. packaging areas) allows enhanced spread of *Listeria* within the processing environment

4. Lack of control measures (like hand washing/foot baths) increases the likelihood of persistent strains spreading to higher-care areas

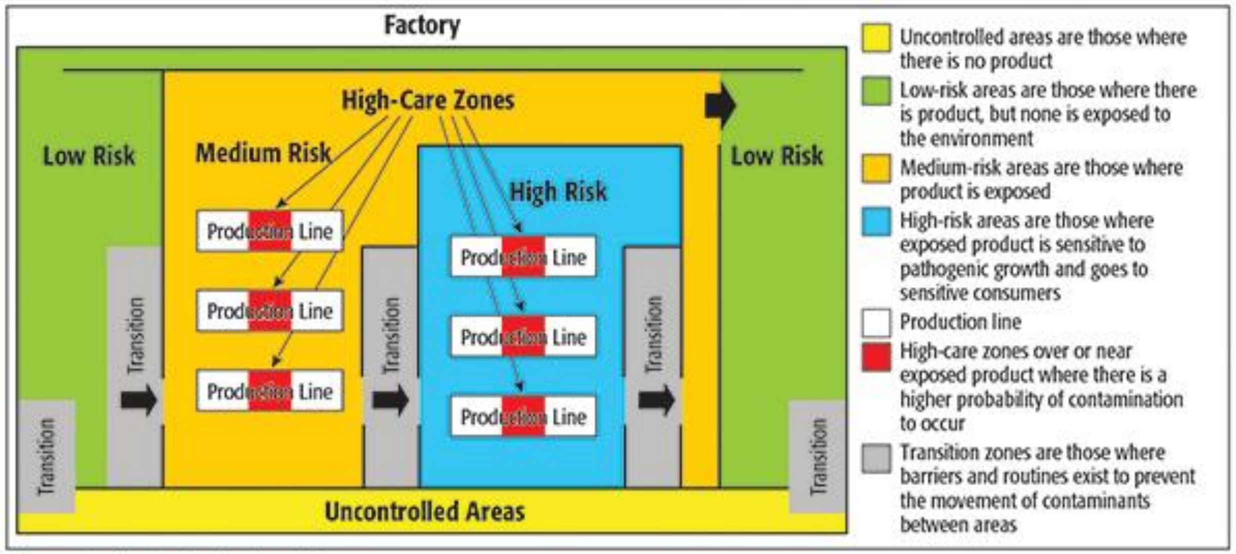


Figure 1. Hygienic Zoning Map

Control *Listeria* Through Transfer Vectors

Transfer Vectors: Certain sites are more likely to represent temporary transfer, especially **mobile items**:

- Employee sites (gloves, boots, boot covers).
- Mobile equipment (carts and cart wheels).
- Cleaning tools (squeegees, brooms, hoses), especially when damaged or containing moisture.

Control of *Listeria* Spreading Through the Floor Drain

1. **Employees** can walk over contaminated drain grates and transfer the bacteria on their shoes / **trolley cart**

2. **Fruit flies, other insects, and other pests -** cause *Listeria* to spread to any part of a facility.

3. **High-pressure spray –** force the bacteria into the air. *Listeria* can still be on the cleaning equipment that is not properly sanitized after cleaning out the drains.

4. **A clogged drain can allow bacteria to grow in standing water**, creating the potential for splashing and overflowing when more liquid enters the drain channel. This can spread contaminated wastewater throughout a facility.

Controls of *Listeria / Salmonella* to Lower the Risk of Contamination in Environment

- **Sanitation and Deep Cleaning Interventions**
  - An effective sanitation plan
  - Cleaning tips for *Listeria* control include:
    - Sanitize equipment/tools before and after use, focusing especially on niches.
    - Keep floors dry and free of standing water.
    - Allow surfaces to dry completely before applying sanitizer.
    - **Routine scheduled equipment disassembly (Periodic Equipment Cleaning, PEC)**

Controls of *Listeria / Salmonella* to Lower the Risk of Contamination in Environment

Environmental Monitoring Programs (EMPs)

- To **prevent cross-contamination** of food products.
- To **verify the effectiveness of sanitation** programs.
- To **identify potential harborage sites** for pathogens.
- To **comply** with regulatory requirements and industry standards.
- To provide data for **continuous improvement** of food safety systems.

Key Components - Environmental Monitoring Program (EMP)

Hygienic Zone Mapping

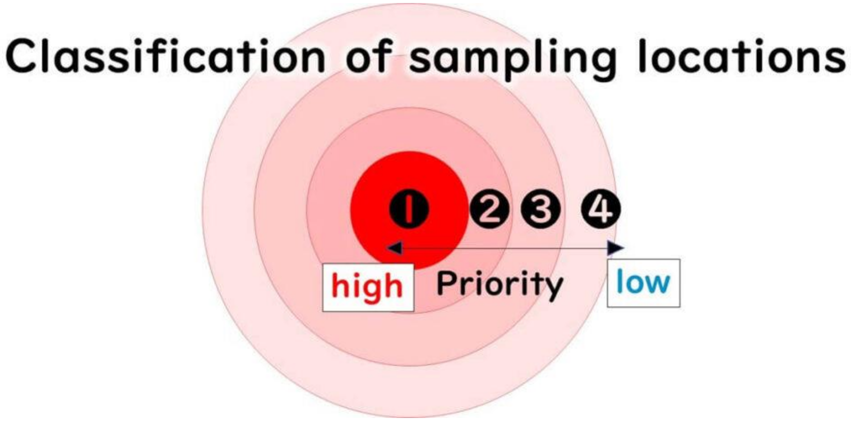
To effectively track pathogens, follow **4 risk-based zones**:

Zone 1: Direct product contact surfaces (e.g., cutting blades, evisceration equipment, conveyor belts).

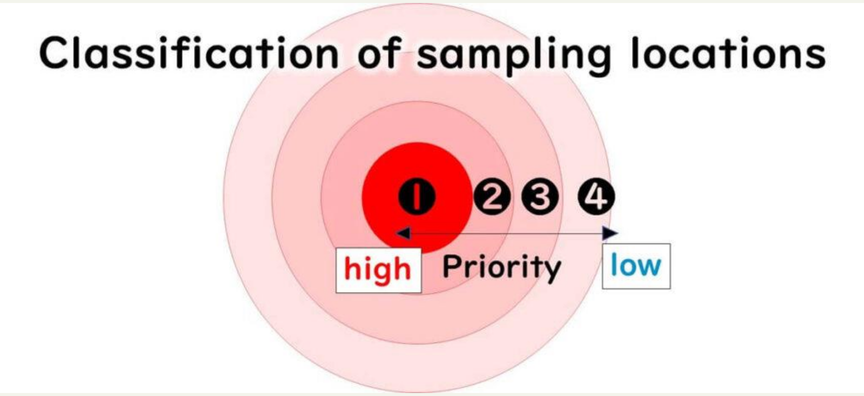
Zone 2: Non-product contact surfaces adjacent to Zone 1 (e.g., equipment frames, structural supports, tables).

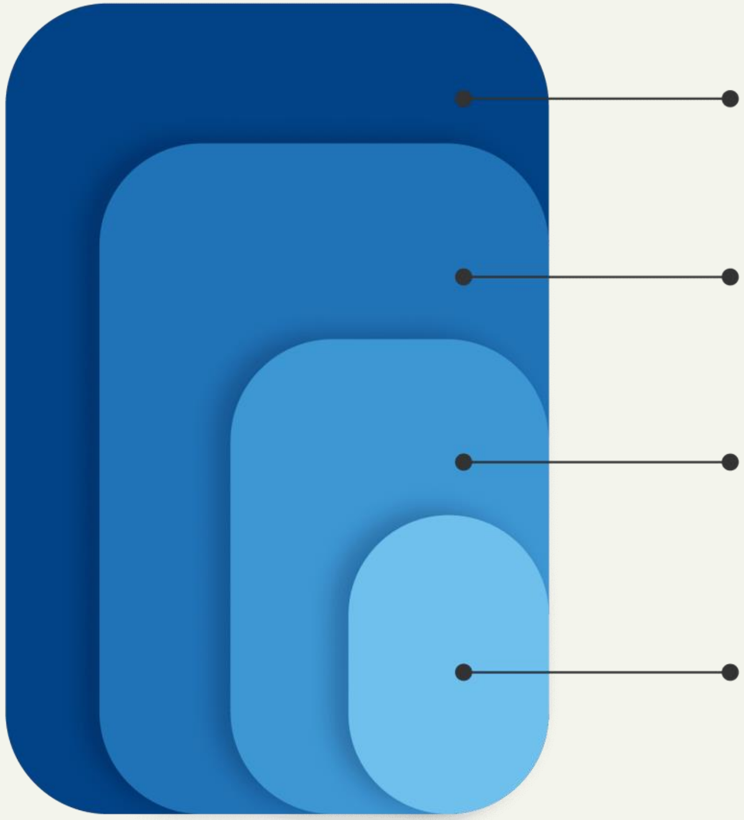
Zone 3: Non-product contact surfaces in the processing area (e.g., floors, walls, drains, forklifts).

Zone 4: Non-production areas outside the processing room (e.g., locker rooms, break rooms, cafeterias, hallways).



Where to Test in the Environment? – Sampling Sites & Zoning Concept





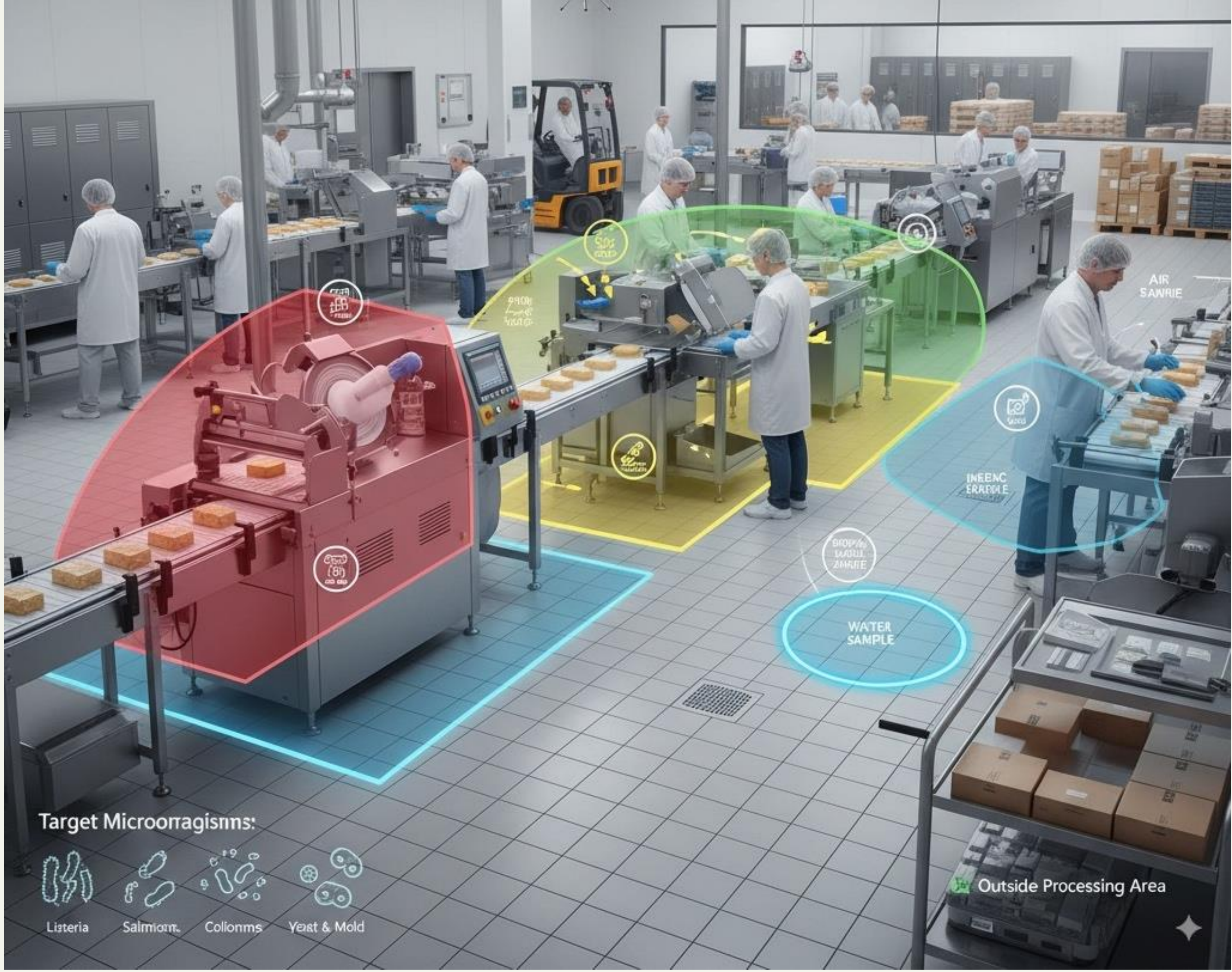
Zone 4
- Exterior production room.
- Lunch rooms
- Maintenance rooms
- Sanitation cage

Zone 3
- Within production room
- Chain Drives
- Interior of equipment

Zone 2
- Adjacent to product contact
- Near conveyer belts
- Table legs

Zone 1
- Direct product contact
- Dripping condensate
- Conveyer belts
- Aprons
- Arm guards
- Gloves
- Control panels

Sampling Zones



Selecting the Right Testing Methods

Common assays used by food and beverage processors for EMP testing

ATP (adenosine triphosphate)

- Effective for quickly monitoring general sanitation before production.
- Detects **residual organic material remaining on surfaces following cleaning**.
- Results are obtained in a matter of seconds.

Coliforms and Enterobacteriaceae

- Indicators of **overall cleanliness**. Include a wide range of microorganisms, including some that are pathogenic, making them effective indicator tests.
- Coliforms are often used as an indicator of potential presence of **pathogenic *E. coli***, while Enterobacteriaceae are often used as an indicator of potential **presence of *Salmonella***.

Total Plate Count (TPC) and Aerobic Plate Count (APC)

- Provide an indication of the **total microbial population on the test surface (both bacteria and fungi).** Serve as excellent indicators of overall hygiene and the effectiveness of sanitation practices.

Yeast & Mold

- Indicates **the presence of fungal spoilage organisms.** Often used with TPC and APC to **verify overall effectiveness of sanitation processes.**

Listeria spp. & *Listeria monocytogenes*

- **The most common assays performed for ready-to-eat food and beverage EMPs.**
- Processors of many RTE foods must monitor for *Listeria* spp. to meet regulatory requirements. Both approaches are used, but monitoring for *Listeria* spp. casts a wider net than *Listeria monocytogenes* testing.

Salmonella

- Facilities that process products susceptible to *Salmonella* contamination, such as **low water activity foods** like almonds and tree nuts, dry cereals, and peanut butter, as well as poultry, eggs, etc., should make this assay part of their EMP.

Controls of Foodborne Pathogens

- Time and Temperature Control for Safety Food (TCS)
- EO water and applications
- Natural antimicrobial compounds (e.g., organic acid and bacteriocins)
- Bacteriophage technology

Time and Temperature Control for Safe Food (TCS)

Food can serve as a culture medium for growth of pathogen at right conditions:

- **Nutrient** - High in protein: milk, poultry, fish, and shellfish (shrimp, lobster, crab)
- **Moisture content** - Moist: meats, poultry, fish, and shellfish (shrimp, lobster, crab), cooked rice, pasta, beans, and vegetables including baked potatoes
- **pH** - Moderately to slightly acidic
- **Temperature** - bacteria like warm temperature
  - lower temperature: stop growing

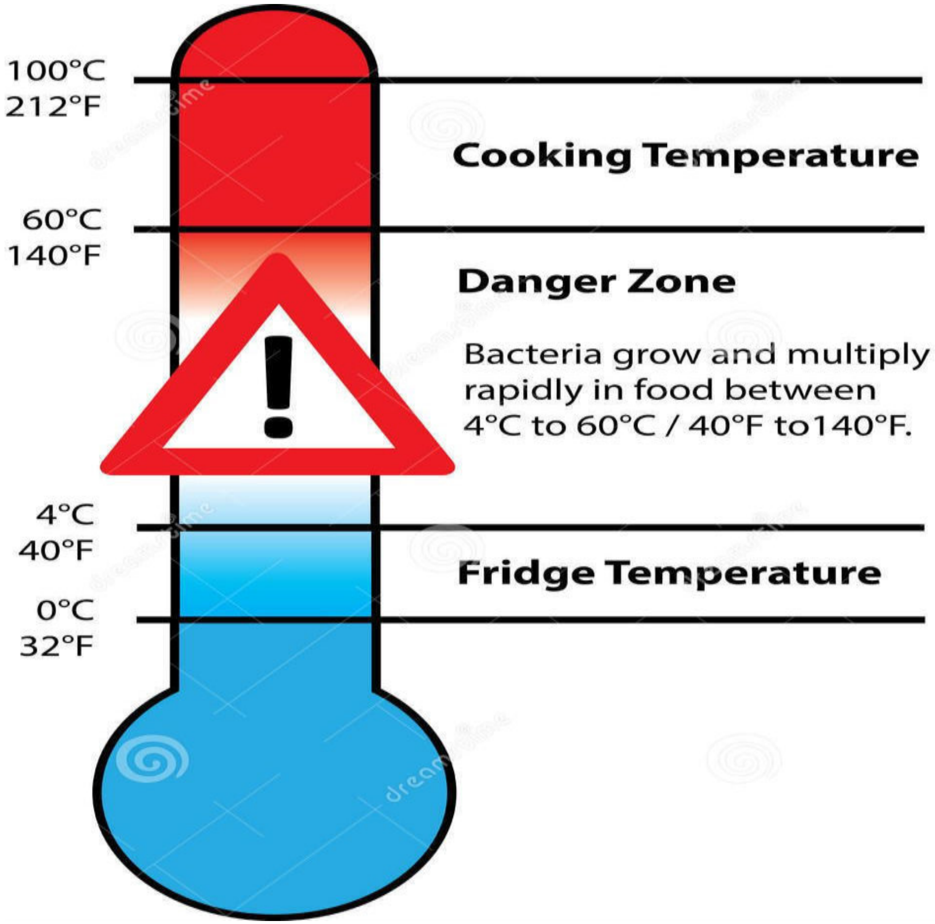


Fig. 5 Temperatures correlating to the danger zone where bacteria grow and multiply.
Source: www.dreamstime.com

TABLE A-2 TIME AND TEMPERATURE GUIDANCE FOR CONTROLLING PATHOGEN GROWTH AND TOXIN FORMATION IN FISH AND FISHERY PRODUCTS		
POTENTIALLY HAZARDOUS CONDITION	PRODUCT TEMPERATURE	MAXIMUM CUMULATIVE EXPOSURE TIME
GROWTH AND TOXIN FORMATION BY ***BACILLUS CEREUS***	39.2-43°F (4-6°C) 44-59°F (7-15°C) 60-70°F (16-21°C) Above 70°F (21°C)	5 days 1 day 6 hours 3 hours
GROWTH OF ***CAMPYLOBACTER JEJUNI***	86-93°F (30-34°C) Above 93°F (34°C)	48 hours 12 hours
GERMINATION, GROWTH, AND TOXIN FORMATION BY ***CLOSTRIDIUM BOTULINUM*** TYPE A, AND PROTEOLYTIC TYPES B AND F	50-70°F (10-21°C) Above 70°F (21°C)	11 hours 2 hours
GERMINATION, GROWTH, AND TOXIN FORMATION BY ***CLOSTRIDIUM BOTULINUM*** TYPE E, AND NON-PROTEOLYTIC TYPES B AND F	37.9-41°F (3.3-5°C) 42-50°F (6-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	7 days 2 days 11 hours 6 hours
GROWTH OF ***CLOSTRIDIUM PERFRINGENS***	50-54°F (10-12°C) 55-57°F (13-14 °C) 58-70°F (15-21°C) Above 70°F (21°C)	21 days 1 day 6 hours[1] 2 hours
GROWTH OF PATHOGENIC STRAINS OF ***ESCHERICHIA COLI***	43.7-50°F (6.6-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	2 days 5 hours 2 hours
GROWTH OF ***LISTERIA MONOCYTOGENES***	31.3-41°F (-0.4-5°C) 42-50°F (6-10°C) 51-70°F (11-21°C) 71-86°F (22-30°C) Above 86°F (30°C)	7 days 1 day 7 hours 3 hours 1 hour

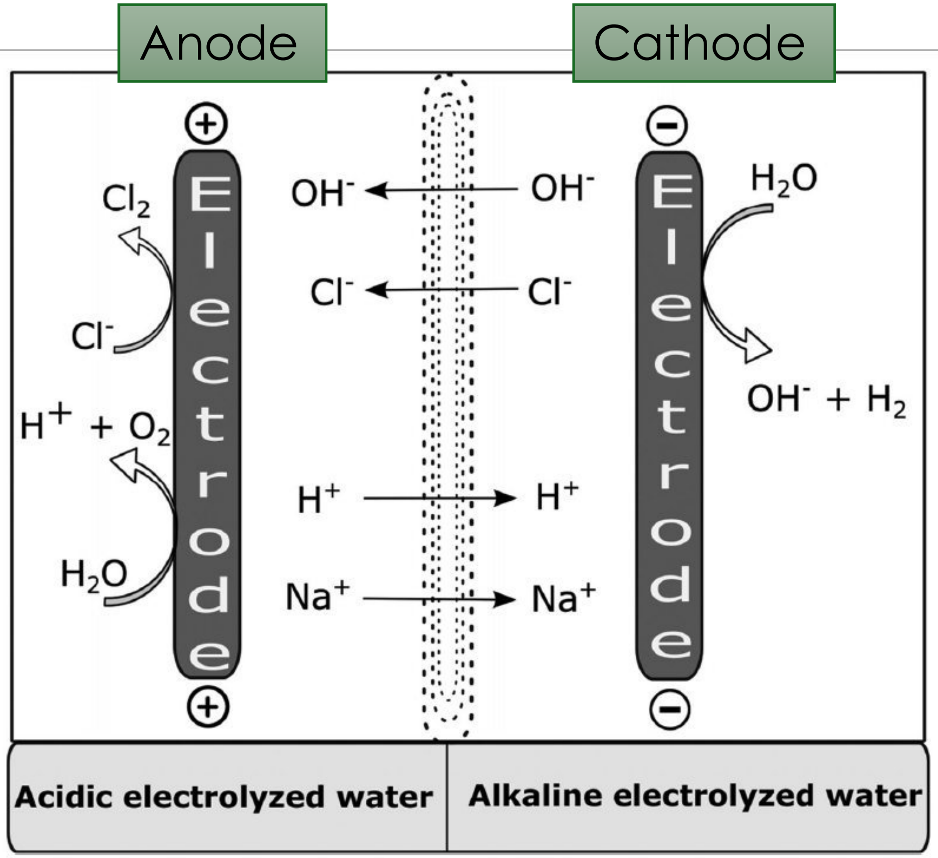
GROWTH OF ***SALMONELLA*** SPECIES	41.4-50°F (5.2-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	2 days 5 hours 2 hours
GROWTH OF ***SHIGELLA*** SPECIES	43-50°F (6.1-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	2 days 5 hours 2 hours
GROWTH AND TOXIN FORMATION BY ***STAPHYLOCOCCUS AUREUS***	50°F (7-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	14 days 12 hours[1] 3 hours
GROWTH OF ***VIBRIO CHOLERAE***	50°F (10°C) 51-70°F (11-21°C) 71-80°F (22-27°C) Above 80°F (27°C)	21 days 6 hours 2 hours 1 hour[2]
GROWTH OF ***VIBRIO PARAHAEMOLYTICUS***	41-50°F (5-10°C) 51-70°F (11-21°C) 71-80°F (22-27°C) Above 80°F (27°C)	21 days 6 hours 2 hours 1 hour[2]
GROWTH OF ***VIBRIO VULNIFICUS***	46.4-50°F (8-10°C) 51-70°F (11-21°C) 71-80°F (22-27°C) Above 80°F (27°C)	21 days 6 hours 2 hours 1 hour[2]
GROWTH OF ***YERSINIA ENTEROCOLITICA***	29.7-50°F (-1.3-10°C) 51-70°F (11-21°C) Above 70°F (21°C)	1 day 6 hours 2.5 hours

1. Additional data needed.
2. Applies to cooked, ready-to-eat foods only.

Electrolyze Oxidizing (EO) Water

- Antimicrobial agent
- Only chemical used in the production is NaCl

Anode: Hypochlorous (HOCl)
acidic electrolyzed water (AEW) or electrolyzed oxidizing water (EOW)



Cathode: NaOH
(Alkaline oxidizing water)

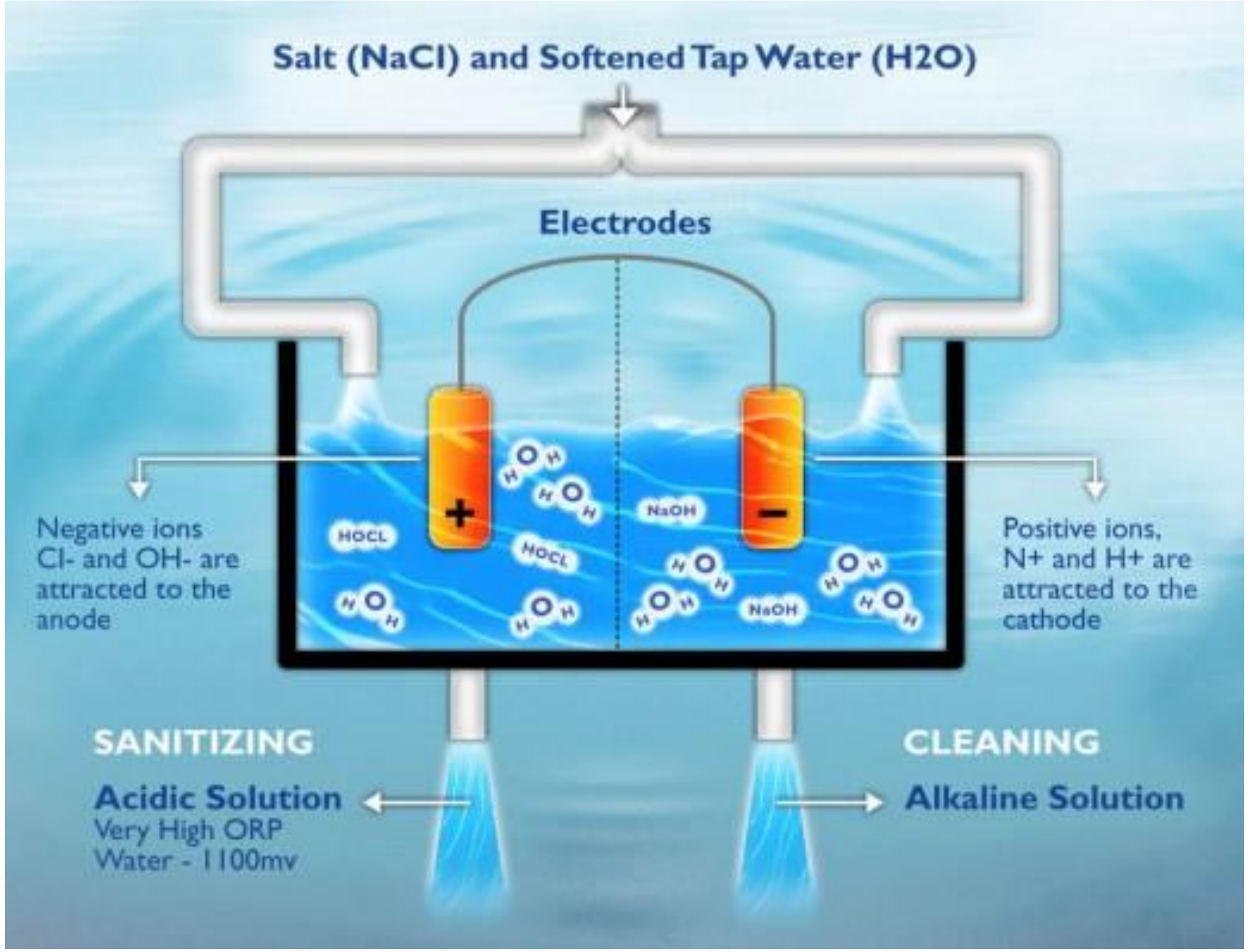
Figure 2–Generation of AEW and AlEW in an electrolytic cell, consisting of anode and cathode connected through an external power supply and separated by a septum or diaphragm. The chemical reactions initiated simultaneously at each electrodes are summarized as follows: at anode: 2 NaCl $\rightarrow Cl_{2\,(g)} + 2\,e^- + 2\,Na^+$, $2\,H_2O_{(l)} \rightarrow 4\,H^+_{(aq)} + O_{2\,(g)} + 4\,e^-$, $Cl2 + H_2O_{(l)} \rightarrow HCl + HOCl$, at cathode: $2\,H_2O_{(l)} + 2\,e^- \rightarrow 2\,OH^-_{(aq)} + H_{2\,(g)}$, $2\,NaCl + 2OH^- \rightarrow 2NaOH + Cl^-$. AEW is obtained from anode, whereas AlEW obtained from cathode.

EO Water Generator

A current across the electrodes will generate:

-**At the anode**, an acidic solution with a pH of 2 to 3, oxidation reduction potential (ORP) *>1100 mV,* and available chlorine concentration (ACC) of 10 to 90 ppm is produced. **This solution is referred to as acidic electrolyzed water (AEW) or electrolyzed oxidizing water (EOW).**

-**At the cathode**, a basic solution with a pH of 10 to 13 and ORP of -800 to -900 mV is produced and this solution is termed as **basic electrolyzed water (BEW).**



EO Water Treatment – Applications in Fish and Seafood products

High ORP = high antimicrobial power

- higher ORP → more oxidation will occur, thus killing the bacteria and unwanted pathogens, by stealing electrons from the bacteria's DNA, cell membranes and proteins → interrupting integrity of membrane structures.

Antimicrobial activity on a wide range of microorganisms: *Pseudomonas, S. aureus, Bacillus* spp., *Salmonella, E. coli* O157:H7.

Treat fish fillets by dipping – to reduce *Morganella morganii* , *Listeria monocytogenes*, *E. coli, Vibrio* spp.

Antimicrobial Compounds from LAB

- Low molecular weight: **organic acids** (produced from lactic acid bacteria): acetic acids (AA), citric acids (CA), lactic acids (LA)
- High molecular weight: **bacteriocins** (produced from lactic acid bacteria): nisin

Organic Acids

- Commonly used in the processed meat, RTE, seafood industry
- LA/AA: produced from lactic acid bacteria.
- Weak acids and do not dissociate completely in water.
- Effective against

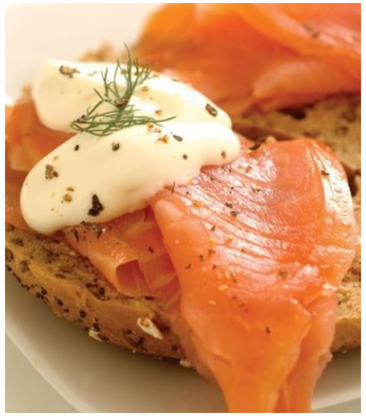
  - Gram-negative bacteria, e.g., *Salmonella* spp. and *E. coli.*

  - Toxin-producing *Clostridium botulinum*.

  - Some fungi
- Mostly salts of organic acids are used (easier to dissolve): sodium acetate (NaA), sodium lactate (NaL), sodium citrate (NaC).

Nisin — Applications in Foods

- Brine shrimps – improve quality and extended shelf-life
- Chilled shrimps – inhibit *Pseudomonas* spp. and H_2S producing bacteria
- In seafood salad (mixed seafood/fish + pickled cucumbers) – inhibit *L. monocytogenes*
- Smoked salmon – inhibit *L. monocytogenes*



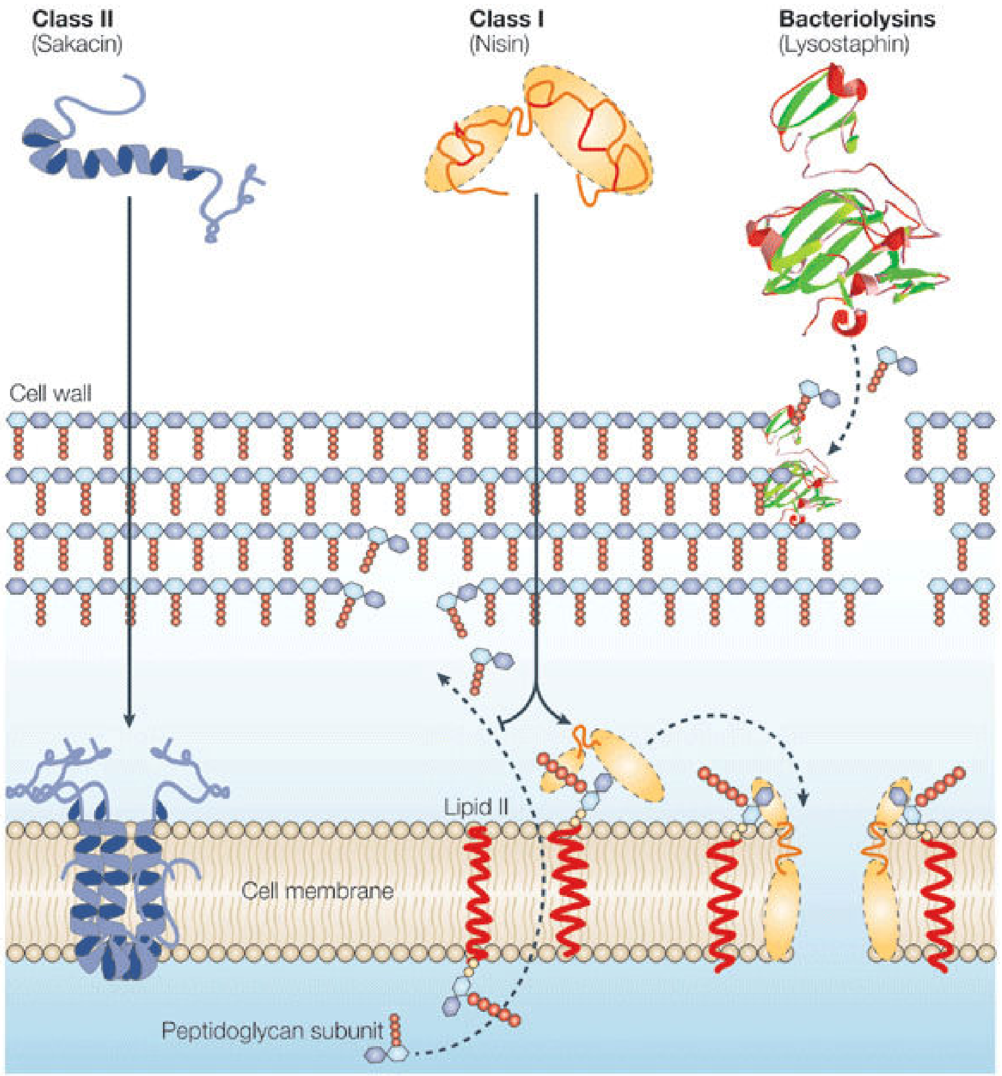
Bacteriocins — Mode of Action & Activity Spectra

- Most commonly used in the processed meat, RTE, seafood industry – nisin
- **Effective against** *Enterococcus*, *Lactobacillus*, *Listeria* spp., *S. aureus*, *Bacillus*, *Clostridium* spp.
- Various mechanisms:

  - inhibiting cell wall synthesis by interrupting the transport channel of PG subunit, leading to cell death.

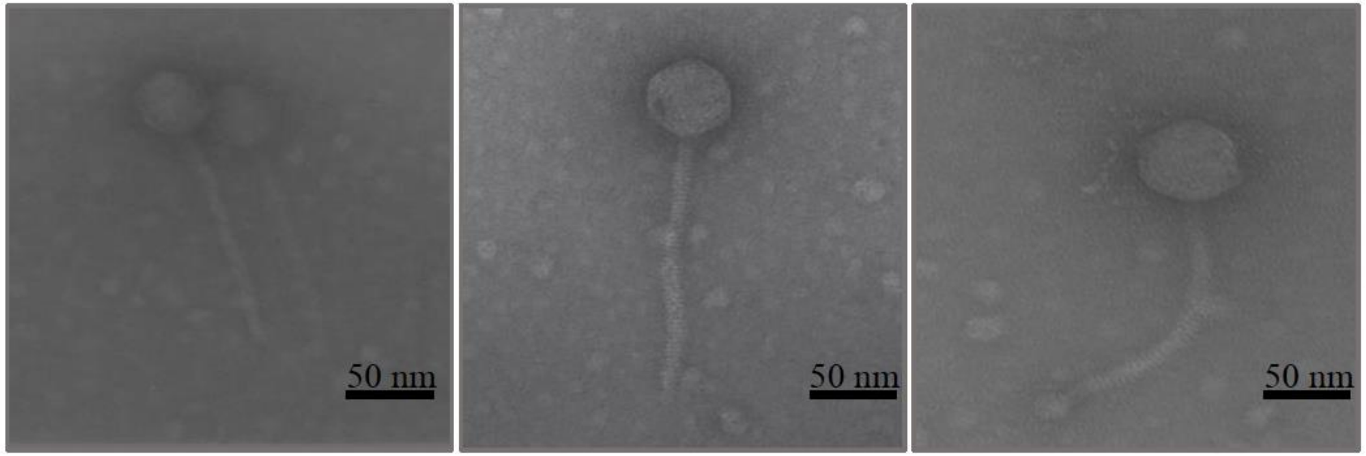
  - function directly to cell wall of G-ve, causing lysis of the cell.

  - insertion to cell membrane causing depolarization, cell leaking, and cell death.

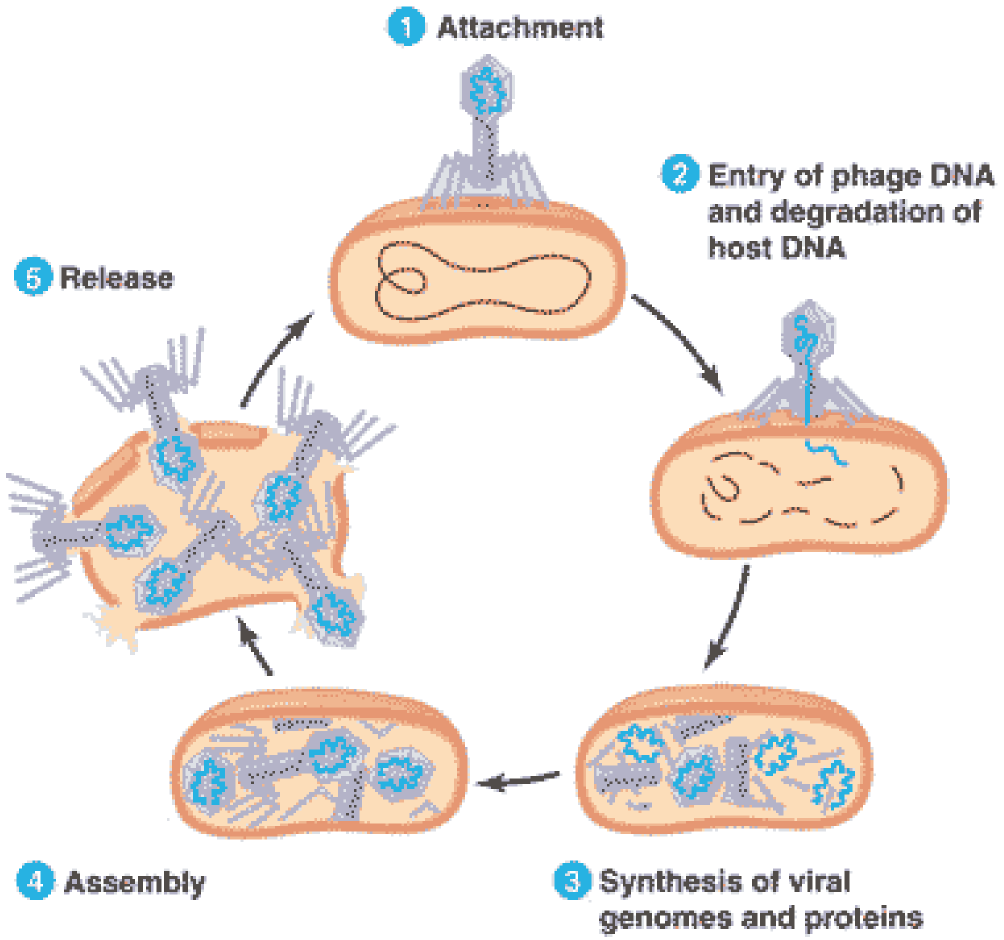


Bacteriophage (phage) Technology

- Virus that specifically infects bacteria (natural bacteria eater)
- Most abundant replicating biological entity on earth (10^{31} – 10^{32}) in environment, feed, food and water
- Generally Recognized As Safe (GRAS) for antimicrobial food additives, e.g., *Listeria* phage, E. coli phage, *Salmonella* phage
- Very specific, natural occurring



How Phages Kill Bacterial Cells



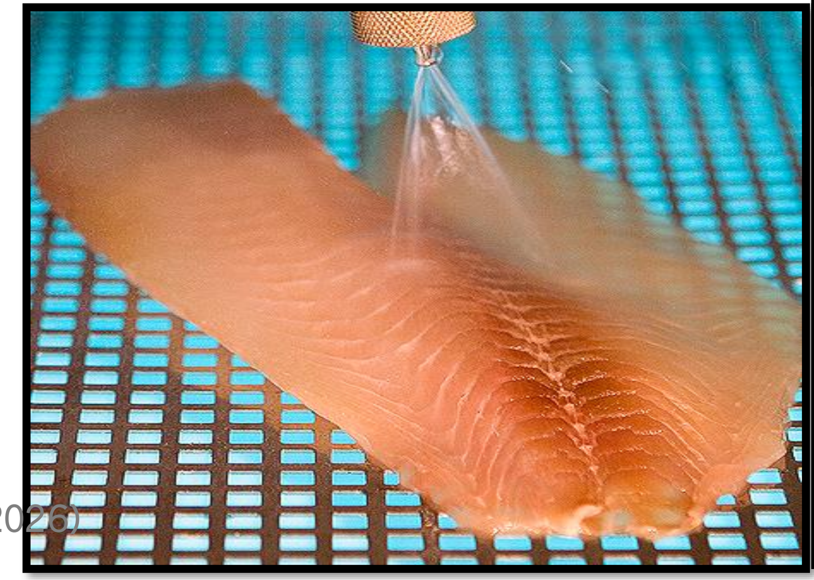
Phage cycle and cell lysis

Phage-based Biocontrol in Foods

Post-harvest Treatments

- "**Antimicrobial food additive**" & Processing aid
- Direct applications of phages onto foods, including use of phages as a dipping/ washing solution on meat carcass

FDA
GRAS APPROVED



Commercial Phage Products for Food Applications

Regulatory approval	Applications
US FDA (2006) and USDA for direct application onto foods (21 CFR 172.785.) EPA (EPA registration 74234-1)	Ready to eat food: salami, sausage, basterami, sea food, food contact surfaces and environments
FDA (2011) cleared as "Food Contact Notification" or FCN, (FCN No. 1018). FSIS Directive 7120.1 (safe and suitable antimicrobial)	Red meat parts and trim intended to be ground
FDA (GRAS Notice No. GRN 000435), FSIS Directive the Star K-certified Kosher and IFANCA-certified Halal product. OMRI-listed suitable in the production of organic foods	Poultry, fish and shellfish, fresh and processed fruits and vegetables
In 2006 approved by the FDA as GRAS, and by the USDA in 2007 and by the EFSA, Health Canada, BAG (Switzerland) and FSANZ (Food Standards Australia New Zealand)	Ready to eat meat, fish, cheese
EPA 2005 for use in agriculture	In agriculture on fruits and vegetables

US, Canada, Israel, Switzerland, Australia and New Zealand have adopted similar regulations for "direct application onto foods".

Integrated Food Safety Strategies

Technology	**Investment**	**Typical Pathogen Targets**	**Best Applications**
Bacteriocins	Medium	*Enterococcus*, *Lactobacillus*, *Listeria*, *S. aureus*, *Bacillus* spp., *Clostridium* spp.	Meat, poultry, seafood
Bacteriophages	Medium	Target-specific pathogens *Salmonella*, *Listeria*, STEC	Meat, poultry, seafood, fresh produce
Electrolyzed Water	Low	Broad spectrum	Meat, poultry, seafood, equipment and environmental sanitation
Organic acids	Low	*Salmonella*, STEC	Fresh produce, packaging
UV-C	Low–Medium	Surface contamination	Equipment, conveyors, packaging
HPP	High	Vegetative pathogens	Ready-to-eat foods, juices, meats

Surveillance and Mitigation Practices Across Food Production

Quality and safety: Raw materials and ingredients

Pathogen kill steps: a process should eliminate pathogens

Post-process control: Materials exiting kill step are subject to recontamination if exposed to the manufacturing environment

Thank you for your attention

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