Food for Public Health Series

Listeria monocytogenes, Listeriosis, and Ready-to-Eat Food Commodities

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Prevalence of *Listeria monocytogenes*

Gram-positive bacterium, *Listeria monocytogenes*, is a significant foodborne pathogen as it can survive diverse environmental conditions, presenting substantial health hazards to humans and animals. *L. monocytogenes*, the most well-known species in the genus *Listeria*, was first identified in 1926. Genus *Listeria* was named after Sir Joseph Lister, a pioneer in antiseptic surgery (1). Since then, 28 species of *Listeria* have been discovered, with *L. monocytogenes* being the primary human pathogen associated with foodborne illness (2). *L.*

monocytogenes is of significant public health concern, characterized by a relatively low incidence of approximately 1,600 cases but a notably high mortality rate of 15.9% per year in the United States (3,4). It can tolerate temperatures as low as <0 °C, a pH ranging from 4.6 to 9.5, and high salt concentrations up to 10% (5). Listeriosis, a deadly disease caused by *L. monocytogenes*, is a significant public health concern. Global incidence of listeriosis ranges from 0.1 to 10 cases per 1 million people annually (6). CDC ranks *Listeria* as the third primary cause of death from foodborne illnesses in the United States, along with severe invasive infections such as bacteremia, meningitis, and pregnancy-associated infections, often leading to a miscarriage or neonatal sepsis. The pathogen primarily enters the host through the intestine, targeting the liver first, and can spread to the brain and gravid uterus in immunocompromised individuals (7). This bacterium exhibits remarkable adaptability to survive in various environmental settings, including soil, water, animal, and food processing facilities. Research indicates that *L. monocytogenes* can be found in various phases of food supply chain, from production to processing, reflecting its persistent nature and challenges in controlling its spread (8). *Listeria* can persist on various surfaces through biofilm formation, a protective shield that protects bacteria from environmental stressors, utilizing quorum sensing. It also exhibits antimicrobial resistance, aiding its survival in food processing environments (9).

Common Food Vehicles and Recent Outbreaks

L. monocytogenes, the pathogen responsible for listeriosis, has been linked to various foods, including ready-to-eat (RTE) foods, raw produce, dairy products, meat, poultry, and seafood. The high prevalence of *Listeria* in food processing facilities and supply chains makes it a significant public health concern (10). One of the potential sources of *Listeria* in the RTE food processing industry is cross-contamination within food processing equipment. As an example, a research study showed that approximately 12.2% sample from two meat processing facilities in China tested positive for *Listeria* with one facility exhibiting a contamination rate of 18.9% and other at 6.25% (11). The risk of contamination is exacerbated due to its ability to survive in extreme conditions, form biofilms, and resist sanitizer. These factors enable them to thrive on surfaces like stainless steel and polyethylene

surface in food processing facilities, increasing the risk of contamination (12). Unpasteurized dairy products, such as Queso Fresco and cotija, are frequently associated with *Listeria* outbreaks. RTE foods, such as prepackaged salads, and deli meats are also significant sources, with specific incidents involving deli chicken salad and ham salad sandwiches (10). Meat and seafood products, including raw, cooked, and frozen items like shrimp, crab meat, and smoked fish, present additional risks. It's ability to survive and multiply under freezing conditions increases the risk of infection (13). There has been a noticeable shift of *Listeria* infection from animal products to diverse produce sources, demonstrating its capacity to infect through a broad spectrum of foods. Recent *L. monocytogenes* infection outbreaks in 2023 have been associated with various food products, underscoring the pathogen's capacity to contaminate both fresh produce and processed meals. The U.S. Food and Drug Administration (FDA) documented several outbreaks linked to frequently ingested products, such as leafy greens, ice cream, peaches, plums, nectarines, cotija cheese, salad mixes, and alfalfa sprouts. Multiple recalls were initiated after the identification of *Listeria* during normal testing and outbreak investigations. Contaminated salad mixes and leafy greens were identified as the source of diseases linked to several states. Likewise, ice cream products were withdrawn following confirmed *Listeria* detections at manufacturing facilities. The contamination of stone fruits, such as peaches, plums, and nectarines, emphasized the risk involved with fresh products, particularly when basic sanitation and processing methods are not maintained. Furthermore, conventional dairy items such as cotija cheese and raw sprouts present significant hazards, underscoring the necessity for rigorous oversight and food safety protocols throughout the supply chain. Additionally, a significant recall of chocolate bars that took place following the detection of *Listeria* during quality control inspection illustrates that even shelf-stable processed food can be susceptible to contamination when sanitary protocols during manufacturing are compromised (14).

Symptoms, Vulnerable Populations, and Health Concerns

L. monocytogenes poses a serious public health concern due to its ability to induce severe infections. The symptoms of listeriosis vary depending on the severity and the individual's health. Mild cases present flu-like symptoms, including fever, muscle aches, and gastrointestinal issues like nausea and diarrhea. In severe cases, the infection can spread to the bloodstream and central nervous system, leading to potentially life-threatening conditions such as meningitis and septicemia. Vulnerable populations are at an increased risk of severe illness from *Listeria* infection. Pregnant women face heightened risks, as listeriosis can result in miscarriage, stillbirth, or premature birth, severely impacting both the mother and the unborn child. Elderly people, immuno-compromised individuals, and neonates are also at higher risk of severe illness from *Listeria*, resulting in high morbidity and mortality (15). In the European Union and the European Economic Area (EU/EAA), individuals aged 64 and older consistently exhibit the highest incidence at the rate of 2.1 per 100,000 people (16).

L. monocytogenes isolates have exhibited resistance to commonly used antibiotics, complicating treatment efforts during outbreaks (17). In Sri Lanka, as an example, raw milk contamination is another concern, with 83% of samples testing positive for *L. monocytogenes* and significant resistance to antibiotics such as penicillin (83.1%) and ampicillin (65%). Emerging antibiotic-resistant strains further complicates treatments, leading to potentially increased mortality (18). These factors, combined with the pathogen's ability to form biofilms and persist in food processing environments, underscore the ongoing challenges in controlling *Listeria* and mitigating its impact on public health. Epidemiological trends indicate a rise

in listeriosis rates in regions like Italy, driven by the prevalence of specific serotypes like 1/2a, 1/2b, and 4b, commonly associated with clinical and food samples (19). The increasing trend of foodborne listeriosis, particularly in the RTE food sector, underscores the ongoing challenges in controlling *Listeria* and reducing its impact on public health.

Prevention Strategies and Regulations

L. monocytogenes contamination can be prevented by adhering to strict food safety practices. Preventing cross-contamination is crucial; raw and processed products should be kept separate, and surfaces and equipment must be rigorously cleaned and sanitized (20). Proper temperature control is also essential; refrigerated foods must be maintained at 41°F or below, and adherence to recommended storage times is necessary. Regular employee hygiene and food handling training are vital for reducing contamination risks. Additionally, implementing stringent cleaning and sanitation procedures is essential for eliminating biofilms, as *Listeria* can persist in these environments. These measures ensure safer food handling practices and protect public health. Effective facility design and routine technical equipment maintenance are vital in preventing contamination (21). Robust monitoring systems such as molecular detection techniques, including Polymerase Chain Reaction (PCR), have improved the identification and monitoring of *L. monocytogenes* in different environments, facilitating better management and control measures to prevent outbreaks (22).

Many countries have set a microbiological criterion of 100 CFU/g for low-risk foods that do not support the multiplication of *L. monocytogenes*. In contrast, the U.S. follows a zero-tolerance policy for all RTE foods, leading to recalls for any positive *Listeria* test results. The Food Safety and Inspection Service (FSIS) enforces this policy in RTE meats, requiring either post-lethality treatments or antimicrobial agents to manage contamination. FDA maintains a zero-tolerance policy but applies this broadly across many foods, emphasizing stringent sanitation, monitoring, and record-keeping (23). Advanced technologies further help with the effective control of *Listeria* management. Biopreservation techniques, including lactic acid bacteria and bacteriocins, can effectively reduce *Listeria* levels in various RTE foods (24). Natural antimicrobial agents, including organic acid (*e.g.,* lactic acid, citric acid, acetic acid) and essential oil and plant-based bioactive compounds (*e.g.,* carvacrol, and thymol), effectively control *L. monocytogenes* by damaging cell membranes and inhibiting metabolic function. Efficiency is further enhanced when combined with advanced processing technologies such as high-pressure processing and irradiation. The combined effect not only reduces *Listeria* population but also inhibits biofilm formation, hence enhancing food safety in RTE food products. Post-package decontamination methods, such as irradiation and high-pressure processing, also effectively control *Listeria* multiplication. Additionally, natural antimicrobial from plant extracts is being explored in combination with irradiation and high-pressure processing, which are also effective in controlling *Listeria* growth (25,26).

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