~ The fantastic journey of *Listeria monocytogenes* ~

~ (*Listeria monocytogenes* in the Food Processing Environments) ~

PART 1 OF 2

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Many of us would agree that food is one of the most important and enjoyable things for humanity. What if you were told that there is a dangerous tiny bacterium that is here to turn our food dreams into starving nightmares? Let our journey to the world of *Listeria monocytogenes* begin!

The *Listeria* genus is comprised of both pathogenic (*Listeria monocytogenes*, *Listeria ivanovii*) and many non-pathogenic (such as *Listeria welshimeri* or *Listeria innocua*) species. *Listeria* are ubiquitous bacteria meaning that they can be found everywhere in the environment. Although *Listeria* are saprophytic organisms living on dead or rotting organic matter such as that from plants, during the end of the 20th century, the first pathogenic strains of *Listeria* started to emerge leading to several outbreaks in Western countries (1, 2). *Listeria monocytogenes* (*Lm*) in particular is the pathogen of the highest importance as it can infect humans. *Lm* was first discovered in 1926 during an epidemic in rabbits and guinea pigs. *Lm* was later characterized in 1986 as a food pathogen infecting both animals and humans leading to the foodborne disease, listeriosis (3).

Listeriosis is a rare disease, but with a high mortality rate, which can be around 20-30%.The populations that are more susceptible to listeriosis are the immunocompromised, elderly, children and pregnant women. Upon ingestion of contaminated food, *Lm* encounters the gut epithelium, crosses the intestinal epithelial barrier and then disseminates via the lymph nodes and the blood to different organs, including the liver and spleen (4). *Lm* can also cross the blood-brain barrier and the fetoplacental unit to cause meningitis and miscarriage, respectively (5). There have been several major listeriosis outbreaks in the past, but the most severe one was recorded back in 2018 in South Africa due to the consumption of Ready-To-Eat (RTE) sausage meat. Around 937 listeriosis cases were documented, of which 216 were fatal (2).

Lm can adapt and contaminate a variety of foods including dairy products including both pasteurised and unpasteurised milk and cheese, meat and fish products and biproducts, as well as fresh and frozen fruit and vegetables (6). However, the foods of highest concern are RTE meals, which according to the European Food Safety Authority (EFSA) account for up to 7.2% of listeriosis transmission and manifestation. RTE foods are particularly of high risk due their consumption without further cooking. But how does *Lm* manage to contaminate the products and consequently us?

It is acknowledged that pathogenic and non-pathogenic species share mutual niches. Therefore, it is possible that the non-pathogenic ones could act as ‘index’ organisms (or supporting evidence) for potential contamination and establishment of *L. monocytogenes* in food processing environments (FPEs) (7). The first-line measures against the colonisation of *Lm* in FPEs are a set of hygiene regimes consisting of cleaning, sanitization and decontamination (8). These regimes contain many disinfectant compounds but amongst them the most important antimicrobial agent are the quaternary ammonium compounds (QACs), which are found in the majority of sanitizers. However, this is a very concerning matter, as *Lm* can acquire resistance to sub-lethal sanitizers, forming disinfectant-resistant and therefore persistent *Lm* strains (7, 8). More specifically, microorganisms that are exposed to such compounds can obtain tolerance under selective pressure events.

Several studies generated in different FPEs and geographical locations have documented re-isolation of the same clone over prolonged periods, suggesting a persistence phenotype of *L. monocytogenes*.

This is considered as an imperative challenge to food industries, as it is possible that persistent *Lm* are linked to an increased likelihood of cross-contamination of food products (9). This tolerance phenotype could be an outcome of the incomplete or unsuccessful eradication of *Lm* in the FPEs.

In addition, both animal and human activity are significantly impacting the dissemination cycle of *Lm* (2). Infected animals can carry *Lm* without any symptoms leading to not only soil contamination (particularly important for fruit and vegetables), and contaminated products (milk) and biproducts (yogurt, cheese etc), but equipment as well. This cross-contamination event can keep repeating, leading to a generic FPE contamination and consequently, to a *Lm* persistence phenotype when the organism colonises the FPE. But by what means may persistence be caused? It may be triggered by several factors such as poor hygiene or ineffective sanitizers, damaged equipment or surfaces that could act as harbourage sites, the presence of genetic markers promoting the specific tolerance and persistence phenotype, as well as both the biofilm formation by persistent strains and their interactions with native microbiota (7, 8, 9).

All in all, *Lm* remains a relevant threat to public health safety which has a profound impact both on society itself, and on the food industries as well. The adaptation of *Lm* to stress conditions encountered in the environment or during infection make this pathogen a real danger, therefore, cellular and molecular research is extensively carried out in order to better understand *Lm* survival and persistence mechanisms, as well as develop both detection and therapeutic techniques in order to decrease the mortality rate of the susceptible population.

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