LISTERIA MONOCYTOGENES IN THE RETAIL FOOD SERVICE ENVIRONMENT

A Paper
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

David Andrew Walpuck

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Program:
Food Safety

April 2018

Fargo, North Dakota

North Dakota State University
Graduate School

Title

LISTERIA MONOCYTOGENES IN THE RETAIL FOOD SERVICE ENVIRONMENT

By

David Andrew Walpuck

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

SUPERVISORY COMMITTEE:

Dr. Peter Bergholz

Chair

Dr. Anuradha Vegi

Dr. Robert Maddock

Approved:

05/31/18 — Date

Paul Schwarz — Department Chair

ABSTRACT

Listeria monocytogenes is one of the biggest microbial concerns affecting today's food industry. It is a ubiquitous liability with a high mortality rate, unique characteristics of growth and survival in many environmental conditions, making the pathogen a true risk to consumer health. Recent outbreaks of listeriosis have caused fatalities, massive well-publicized recalls costing the food industry heavy financial losses and damaged reputation. *L. monocytogenes* is the forefront of impediment and educational efforts from private industry and government agencies. The purpose of this study is to assess the features and concern of *L. monocytogenes* in the retail food service environment and its impact on operations. Regulatory surveillance of testing environmental samples and food products for *L. monocytogenes* highlight prevention. Organizations in the retail food service industry need a separate plan for training, food handling, sanitation and financial allocation to combat the potential threat of *L. monocytogenes* contamination.

ACKNOWLEDGEMENTS

Thanks to Dr. Peter Bergholz for all of his efforts, educational advice and professionalism, as well as the other members of my committee, Dr. Anuradha Vegi and Dr. Robert Maddock. David Saxowsky was also a positive influence on my development at North Dakota State University. Shannon Ueker was instrumental in assistance. Sincere gratitude to my family and friends for all of their love and support.

TABLE OF CONTENTS

ABSTRACT iii

ACKNOWLEDGEMENTS iv

LIST OF FIGURES vi

LIST OF ABBREVIATIONS vii

INTRODUCTION 1

CHARACTERISTICS OF *LISTERIA MONOCYTOGENES* 6

ENVIRONMENTAL CONDITIONS 12

LISTERIOSIS 20

Incubation Period 21

At Risk Populations 21

Infective Dose 21

Carriers 22

OUTBREAKS/FOOD SOURCES 24

PREVENTION - RELEVANT TO A RETAIL FOOD SERVICE ENVIRONMENT 29

Cleaning, Sanitizing and Other Preventive Measures 31

Surveillance 35

EDUCATION 38

IMPACT ON THE RETAIL FOOD INDUSTRY 41

CONCLUSION 43

REFERENCES 46

LIST OF FIGURES

Figure Page

1. a) Interior of deli display case with vent covers missing b) Interior of deli display case with 4-month-old deli meat 3
2. Characteristics of *L. monocytogenes* 8
3. Pitted contact surface holding arm of deli slicer which is a niche area for microbial harborage 9
4. Zones of potential *L. monocytogenes* contamination where Zone 1 is closest to a food source and Zone 4 can be an introductory area into food processing 12
5. a) Floor drain b) Soiled interior of display case 14
6. a) Chipped and peeling interior wall of display case that creates a potential microbial harborage area and physical hazard to food b) Wrapped, undated cut deli meats in refrigerator where time and temperature are critical aspects in controlling bacterial growth 15
7. Potential biofilm formation in hand sink stain 18
8. The timeline for a listeriosis outbreak typically takes between 2-10 weeks, or even longer. Cases can continue to increase and may have been linked years earlier 24
9. Estimated risk percentages of *L. moncytogenes* contamination in a retail deli environment 29
10. Three steps to control *L. monocytogenes* 30
11. Cleaning equipment soaking in food prep sink, which is a potential spread of contamination to food contact surfaces 33
12. Types of logs to document complainace 35

LIST OF ABBREVIATIONS

L. monocytogenes	*Listeria monocytogenes*
pH	Potential of hydrogen
CFU	Colony forming unit
FDA	United States Food and Drug Administration
ppm	Parts per million
Quat	Quaternary ammonium
CDC	Centers for Disease Control and Prevention
FIFO	First in first out
spp	Species
FSIS	United States Department of Agriculture Food Safety and Inspection Service

INTRODUCTION

For me, as a food safety practitioner who has been in the industry for 30+ years and a father of 4-year-old twins with elderly family members, *Listeria monocytogenes* is of great concern, both personally and professionally. Regulatory agencies charged with the responsibility of protecting public health have a "zero tolerance" for presumptive positive product tests and swabbing of equipment and environmental surfaces for *L. monocytogenes*. There needs to be a better focus, understanding and foresight of *L.monocytogenes*, along with the potential liability it presents throughout the retail food service industry.

Conversely, there are people who feel like the FDA and other regulatory agencies are too aggressive in their pathogen-testing programs, recall decisions and closure of food processing areas for the existence of *L. monocytogenes*. They "Don't Believe the Hype".

"The cold facts and still they try to Xerox.

Leader of the new school, uncool.

Never played the fool, just make the rules.

Remember there is a need to get alarmed.

Again, I said I was a time bomb.

In the daytime, the radios scared of me.

Cause I'm mad, plus I'm the enemy." (Ridenhour, *et al.*, 1988)

Ironically enough, *Listeria monocytogenes* is a public enemy and fits well with the lyrics. Controlling "hype" and clarifying food safety fact versus fiction is a constant responsibility. Communication style in food safety, whether it is the Queen's English or Gangster Rap, it has to include the appropriate audience, timeliness and leave an impactful message that is bold and brief, leaving the listeners wanting more.

The CDC estimates that *Listeria monocytogenes causes* 1,600 illnesses, 1,500 hospitalizations and 260 deaths each year in the United States. Consuming contaminated food is the primary route of transmission. *L. monocytogenes* is an omnipresent pathogen that can survive in a variety of environments, including freezing, sometimes for years. Deli products as well as other ready-to-eat food products are recognized as high risk in the retail food industry (FSIS, 2015). The 2000 outbreak strain of *L. monocytogenes* associated with turkey deli meat in the United States reportedly persisted in the processing environment for more than 10 years (Kathariou, 2002).

There is a greater need for site-specific modeling (not all facilities are the same) for potential contamination from *Listeria monocytogenes* in the food processing facility. Retail food establishments are unique because they vary on how food is processed. Some cook, cool, hold and display food while others make food products to order. Condition of equipment, environmental factors and flow of food must be specifically addressed in each location to eliminate the potential of *L. monocytogenes* contamination. Modeling should include all of the different variables within a given facility, such as the specific type of product processed, volume and facility layout to better understand potential contamination. These models could also assess the needs of a food processing facility and the costs associated with critical control points and corrective actions. Theoretical studies of a particular location could help address outcomes and predictive analysis of food safety measures to combat *Listeria monocytogenes* (Kathariou, 2002).

Unseen circumstances in the retail food industry can lead to potential consequences with consumer health, increased regulatory surveillance, liability and expense. At any time a situation can arise that can become life threatening for some and jeopardize a career for others. Figure 1 a) & b) below are the deep interior of a deli display case, where the cover from

the vent was removed and chunks of 4-month-old cut and wrapped deli meats along with food debris were found. Speculation is that the vent covers may have been removed and the deli meats thrown in the bottom mechanical area of the display case by a disgruntled employee. Alternatively, a refrigeration technician may have removed the vent cover during a repair and the product fell into the area by accident. Either scenario presents a true concern for *Listeria monocytogenes* contamination in the retail food service industry for the presence and spread of the pathogen.

Figure 1. a) Interior of deli display case with vent covers missing. b) Interior of deli display case with 4-month old deli meat.
Source: Image by David Walpuck

I will argue that operators of retail food service operations who primarily serve ready-to-eat food should have a **separate plan** in place to protect against potential contamination from *L. monocytogenes*. Aspects of these preventive measures should include:

- Allocation of funds specific to *L. monocytogenes* prevention to be included in the budget and a line item in the profit and loss statement under store maintenance. Stores assessed on need, square footage, amount of perishable departments (areas that actively process food from a raw state, such as a food service department) and volume.

- Risk assessments done at all retail locations to assess the potential introduction, presence and spread of *L. monocytogenes*.
- Detailed cleaning and sanitizing programs that include a more frequent use of third party cleaning companies to clean processing areas and floor drains on a more frequent basis.
- Rotation of sanitizers and steam heat treatments on intricate pieces of equipment that contact ready-to-eat food products.
- Cleaning and sanitizing logs will be required to submit for review on a monthly basis, which will involve notification and follow up with all district managers. Compliance will be part of the bonus structure for all store management.
- Robust facility and equipment maintenance on niche areas that may harbor *L. monocytogenes*. Areas assessed on risk and prioritized in store maintenance budgets.
- Frequent environmental and product testing for the presence of *Listeria* spp.
- Review of food recipes for products produced at store level for acidification.
- Collaborating with regulatory agencies on *L. monocytogenes* prevention, obtaining feedback on what other retail food service operations are doing for prevention.
- Collaboration with vendors on what they doing or can do for the prevention of *L. monocytogenes*.
- Increased hands on training at the store level for food handlers in the field for *L. monocytogenes* prevention. This is to include, quality assurance, operations and merchandising teams. Food safety class will include a more in-depth lecture on *L. monocytogenes* prevention.

While this plan may seem to fit all foodborne pathogens, *Listeria monocytogenes* needs to be recognized for its unique characteristics and the persistence needed to control its harborage,

colonization and spread. *L. monocytogenes* has a dramatic influence on the regulatory agencies with the responsibility of protecting public health and industry cost associated with product recalls, prevention and damaging reputation. All of which will be discussed in this research paper.

CHARACTERISTICS OF *LISTERIA MONOCYTOGENES*

Listeria monocytogenes route of entry is oral, has the ability to spread from cell to cell in the host and when the pathogen enters the monocytes, macrophages or polymorph nuclear leukocytes, it can become blood borne. The health condition of the host is what determines the severity of the *L. monocytogenes* infection (FDA, 2017). Since low detectable levels of *L.monocytogenes* are found in ready-to-eat foods such as deli meats and salads, consumers are exposed to the pathogen billions of times a year. This is inconsistent with the low levels of reported listeriosis cases by the CDC. Only immunocompromised individuals, infants, pregnant women and elderly people is when the severe infection of invasive listeriosis occurs most frequently (Gombas, *et al.*, 2003). The incidence of listeriosis caused by *L. monocytogenes* is increasing worldwide. This is due to better diagnosis and awareness. Susceptible populations are increasing (people live longer) and the amount of foods that support the survival and growth of *Listeria monocytogenes* are increasing as well (Farber & Peterkin, 1991).

There are five other species in the genus *Listeria*: 1) *L. grayi*, 2) *L. innocua,* 3) *L. Ivanovo,* 4) *L. steelier and* 5) *L. welshimeri. L. ivanovii* is pathogenic and found mostly in animals, rather than humans (FDA, 2017).

Virulence is an important factor to take into consideration when developing plans to prevent contamination of *L. monocytogenes*. The virulence of *L. monocytogenes* is a complex life cycle where host cell adhesion, invasion, intracellular multiplication and motility, and intercellular spread categorize the proliferation of the pathogen. Each stage is dependent on the activity of specialized bacterial factors, controlled by a specific set of regulators. Some virulence factors also assume an important role in bacterial resistance and invasion to host defense mechanisms. The optimal temperature of virulence for *Listeria monocytogenes* is 102°F (Doyle,

2001). Serotypes of *L. monocytogenes* are classified by variation in the somatic and flagellar antigens; 1/2a, 1/2b and 4b cause the most foodborne illnesses. The designation of a serotype is associated with the virulence potential of *Listeria monocytogenes* (Borucki & Call, 2003).

L. monocytogenes is characterized as being widespread throughout the environment, including water. When surface waters were tested from the South Nation River in Canada, 75 of the 314 samples were positive for *Listeria monocytogenes*. The watershed is dominated by development from rural and urban development, as well as agricultural crops and livestock. Exposure to humans can be an ingestion of uncooked produce irrigated with contaminated water, crops fertilized with manure containing *L. monocytogenes* carried in asymptomatic animals or consumption of contaminated raw bivalve shellfish. Water was also found to be contaminated with *L. monocytogenes* in 5 of 128 (3.9%) samples of river and lake water from Northern Greece. *Listeria monocytogenes* distributed in watersheds is a significant source of transmission to livestock and wildlife (Lyautey, *et al.*, 2007).

The characteristics in Figure 2 represents how the pathogen differs from other bacteria such as *salmonella* in terms of how hardy and widespread *L. monocytogenes* can be. Retailors in the food service industry need a specific plan to control *Listeria monocytogenes*. Targeted food safety measures against other foodborne pathogens would be potentially ineffective against *L. monocytogenes*.

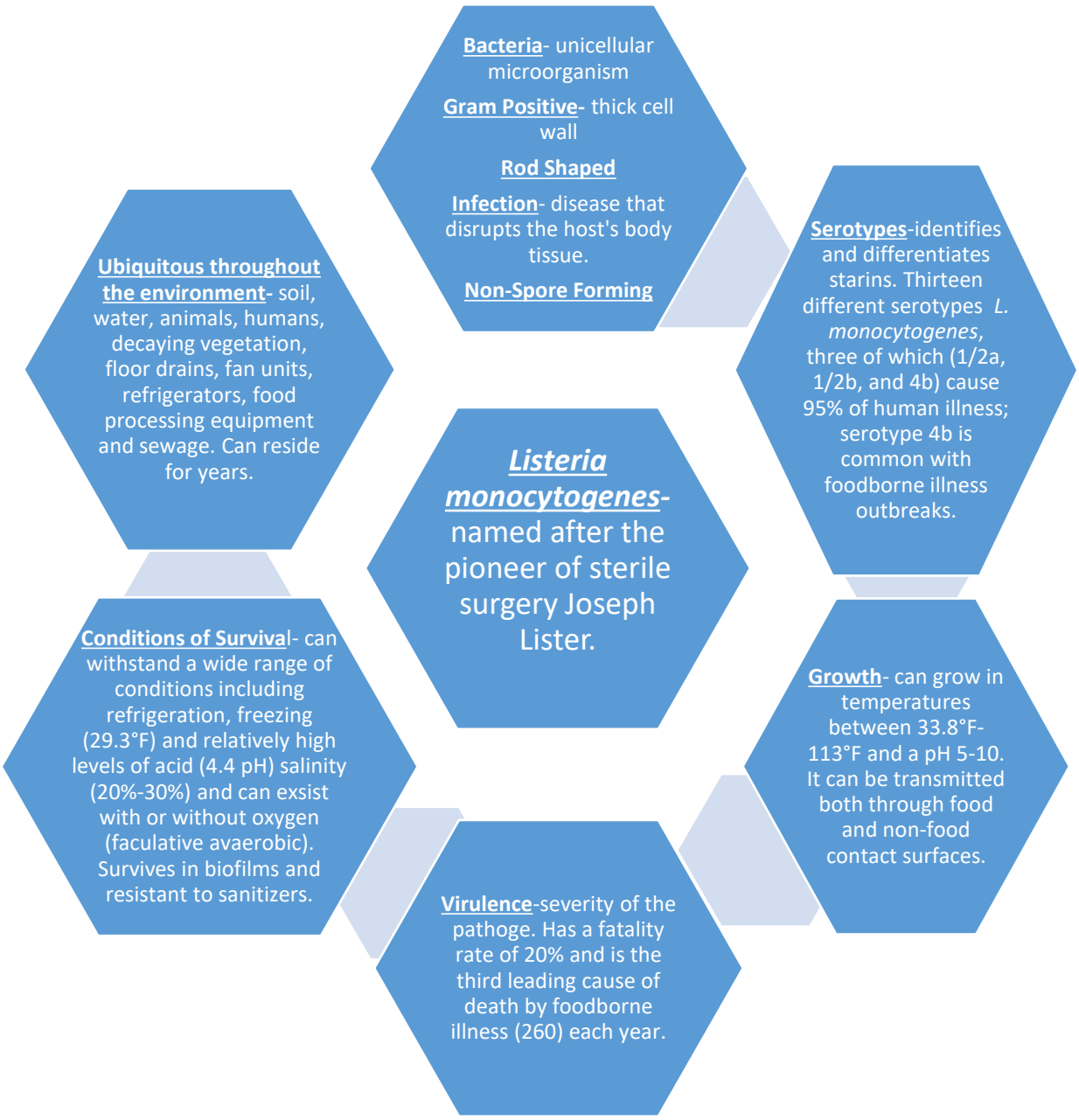

Figure 2. Characteristics of *L. monocytogenes*.
Source: FDA, 2017

Since *L. monocytogenes* is found in ready-to-eat foods after processing, growth and further contamination can occur in these products after they are opened, even under refrigerated temperatures, which elevates the risk for consumer consumption. Sliced deli meats in the retail food industry are a concern because they are processed in a prep area that is not under refrigeration. Deli meats are cut on a difficult to clean slicer and if the equipment is neglected to be properly cleaned and sanitized on a frequent 4-hour basis there is potential for *L. monocytogenes* growth (FDA, 2013). A pitted, cracked, chipped or damaged contact surface, like the product-holding arm of the deli slicer in Figure 3 can be a microbial harborage area. Conversely, if the deli meat was contaminated with *L. monocytogenes* after processing, then sliced on a retail deli slicer, the contamination could cross to the contact surfaces of the equipment. If the deli meats were potentially stored in a cooler or display case that has problems with proper cold holding temperature, condensation and sanitation, it provides optimal conditions for microbial growth, especially *L. monocytogenes* (FSIS, 2015).

Figure 3. Pitted contact surface holding arm of deli slicer which is a niche area for microbial harborage.
Source: Image by David Walpuck

If you also take into consideration that ready-to-eat deli meat is not cooked before consumption, where there is a “kill step” for eliminating pathogenic concerns, all of these factors add up to an increased risk with the product. Ready-to-eat deli meats and deli salads are a high risk for causing listeriosis. In samples obtained from processed deli meats and salads at a retail

establishment showed out of 75 deli salads sampled, 4 were positive for *L. monocytogenes* (5.3%) and of 108 deli meats sampled (both intact and sliced) 1 was positive for *L. monocytogenes* (0.9%). The concern is the growth of *L. monocytogenes* after post processing contamination (Saunders, *et al.*, 2009).

In a study done pertaining to *L. monocytogenes* contamination in a retail food environment, the data collected showed that there was 5 times as many positive samples of "store made" deli meats, deli salads and seafood salads than the same "manufactured" and packaged products. Inadequate refrigeration temperatures in retail display cases and additional product handling in the store made deli meats and salads could have resulted in the increased growth levels of *L. monocytogenes* (Gombas, *et al.*, 2002). These three exact same products have been recently targeted for microbial testing in retail grocery stores from the New York State Department of Agriculture and Markets. Keep in mind that this study was done sixteen years ago, suggesting that these very same products will continue to present *L. monocytogenes* risk to retail food service operations.

L. monocytogenes was isolated from at a high percentage rate from the following foods. Ground veal 100% (3 of 3 samples were positive), ground pork 94.7% (18 of 19 samples were positive), ground beef 77.3% (17 of 22 samples were positive) and raw chicken legs 56.3% (9 of 16 samples were positive). Suggesting that *Listeria monocytogenes* can be present in a variety of raw animal products and processing environments (Farber, *et al.*, 1989). Fluid from raw animal proteins is common threat for cross contamination in a retail food service environment, since many of the raw products processed (poultry, beef, pork & seafood) can be either made-to-order requiring further handling or stored next to ready-to-eat foods.

Another research study done on the presence of *L. monocytogenes* in food found that out of 103 studied samples, 3 of them (2.9%) contained *L. monocytogenes*. Lettuce, both raw 1 (10%) and ready-to-eat 1 (10%) and raw pork 1 (20%) were the positive products. Interestingly enough, *L. monocytogenes* was not isolated from beef or any species of fish that was tested (Soriano, *et al.,* 2000). Produce, especially grown on the ground, contacts soil, which can be a source of *L. monocytogenes*.

Fresh water fish sampled for *Listeria monocytogenes* in India for a study of the pathogen's prevalence in seafood found that of the 200 samples, 67% contained *L. monocytogenes*. Fish and fish products from tropical regions have a low rate of *L. monocytogenes* as well as fish products that are heat-treated and cured. Cold smoked fish have a high prevalence of *Listeria monocytogenes* (Shantha & Gopal, 2013). Contamination of cold smoked fish occurs during the fileting operation, the injection of recirculated brine or on areas of the fish where there was excessive bruising. This is due to *L. monocytogenes* being present on the surfaces of the raw fish when it enters the processing plant, whether it is fresh or frozen. *Listeria monocytogenes* was isolated from 4 of the 19 samples of slime on the exterior of the fish, 30 of 46 skins, 8 of the 17 fish heads and 6 of 9 tails that were sampled. The bruises on the fish that were sampled (2 of 5) also showed presence of *L. monocytogenes.* The temperature of the cold smoking process that was 72°F-87°F, did not eliminate the presence of *L. monocytogenes* and when smoke was added, the presence of the pathogen actually increased three fold. Steps taken to control *L. monocytogenes* in cold smoked fishery products and processing areas include: 1) Elimination of *L. monocytogenes* on the surfaces of the fish before they are processed. 2) Prevention of recontamination during all steps of processing. 3) Preventive measures taken during distribution or retail at the consumer level (Eklund, *et al.*, 1994).

ENVIRONMENTAL CONDITIONS

How and where contamination of *Listeria monocytogenes* can occur in a retail food processing environment as well as colonization of the pathogen has to be understood and assessed. This will help adequately plan preventive measures.

Listed below in Figure 4 are the areas of potential contamination of *L. monocytogenes*. Each area is broken down into a specific zone based on how close the proximity is to a food source or contact surface (Nicholson-Kramer, 2016). Speculation is that most individuals working in the retail food service industry would not correlate an employee locker room (Zone 4) with being a potential breeding and harborage area of *Listeria monocytogenes*, just maybe the realization of a potential source for a cockroach or bedbug infestation. Leftover food, soda cans and personal items left in vacant lockers from past employees; unattended and uncleaned for an extended period can be an issue. That area can get ugly if not maintained. This is why sanitation programs need to address all of these areas on a consistent basis with a specific plan to combat the introduction and spread of *L. monocytogenes* into a food-processing environment. Zone 4 should also include soil and mud controlled in the immediate area outside the establishment. If tracked in, it could provide the introduction of *L. monocytogenes* inside a facility.

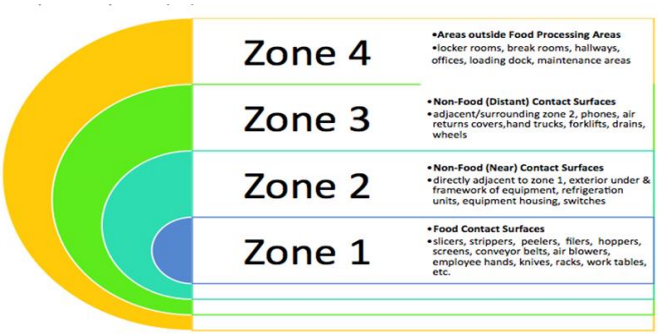

Figure 4. Zones of potential *L. monocytogenes* contamination where Zone 1 is closest to a food source and Zone 4 can be an introductory area into food processing.
Source: Food Safety Tech, 2016

Through strain subtyping, it can be determined whether a strain of *L. monocytogenes* is transient or resident. Resident strains have been found in different food product producers, lingering for years and processed in a common food facility where *L. monocytogenes* can compete effectively against other bacteria (Kathariou, 2002). This makes a case that food processors have a targeted plan against *L. monocytogenes*.

Produce storage, prep and retail sales areas should not be underestimated for the potential presence and growth of *Listeria monocytogenes*. Soil and water are key factors found on all fruits and vegetables grown in or on the ground. The produce floor drain is a risk for *L. monocytogenes*. Making that drain, if backed up and causing pooled water on the floor (whether a storage, prep area or walk-in cooler) a very real concern (Saunders, *et al.*, 2009). Employee shoes and cartwheels that migrate from place to place can be a mode of transmission. In some instances, produce deliveries are stored directly on the floor before they are staged for pack out, processing or storage because there is a lack of dunnage racks to keep the products at least 6" off the floor (FDA, 2013). That is clearly a potential risk. Floor drains and interior mechanical/piping areas of display cases in Figure 5a and Figure 5b are frequently over looked by food service operators for proper detailed cleaning and sanitizing to prevent the colonization of *L. monocytogenes*. These areas need to be addressed on a routine cleaning schedule to minimize the threat of potential contamination. The pitch of the floor drain and interior display case has to allow for proper drainage. Residual standing water from cleaning in and under the case and build-up of condensation runoff, (beading or dripping) can lead to the spread of contamination. Foaming sanitizing agents such as Altima or Eliminex need to be applied in floor drains, on floors, walls and equipment after cleaning on a routine basis to combat the spread and growth of *Listeria monocytogenes*. High-pressure hoses should not be used because of the risk of

aerosolized contamination of food, equipment, utensils, linens and packaging (Food Manufacturing, 2006).

Figure 5. a) Floor drain. b) Soiled interior of display case.
Source: Image by David Walpuck

Listeria innocua was used in an experiment to show the relationship and spread of aerosolized *Listeria* from a contaminated floor drain by spraying a hose directly into a drain. The *Listeria* was detected as far away as 4.0 meters from the drain and on walls as high as 2.4 meters, 4.0 meters away from the drain (Berrang & Frank, 2012).

Equipment (both food and non-food contact surfaces), floors, walls and ceiling that are damaged, chipped cracked or otherwise compromised, provide a harborage area for *Listeria monocytogenes* because they are deemed "not easily cleanable" They need to be repaired and replaced as part of a preventive maintenance plan. The pictures below are the interior of a display case where wrapped deli meats are stored, often leaning or in direct contact with a compromised environmental surface. One can only surmise that the chunk of wrapped deli meat in Figure 6b on the bottom of that pile is a risk, especially if it is thermally abused, not rotated properly using FIFO or the area is unsanitary. If the wrapped deli meats are not properly date labeled with a 7-day "use by" date, it will give a pathogen like *Listeria monocytogenes* time to

expand its CFU (FDA, 2013). The area below in Figure 6a is next to the ventilation grate of the unit where airflow and condensation (especially if it is blown or dripping) can also contribute to the potential risk of *L. monocytogenes* contamination. The peeling/chipped surface can also be a potential physical hazard to food.

Figure 6. a) Chipped and peeling interior wall of display case that creates a potential microbial harborage area and physical hazard to food. b) Wrapped, undated cut deli meats in refrigerator where time and temperature are critical aspects in controlling bacterial growth.
Source: Image by David Walpuck

Ventilation and airflow play an important role in how *L. monocytogenes* can travel, especially from high air pressure areas to low air pressure areas. Air in a room will not be contaminated with *L. monocytogenes* (I was once told by a prominent microbiologist that bacteria could not fly), however air from compressed air lines or air currents from a floor drain too close to equipment when there is a change in water levels, is another story (Tompkin, 2001).

Dust from construction can cause contamination of resident *Listeria monocytogenes* on equipment surfaces, food or packaging. Demolition of floors, walls and ceilings, especially with sheetrock, tiles or plaster can create excessive dust. It can travel easily from area to area through airflow or equipment and be difficult to detect and manage.

Ventilation grates, depending where they are located on equipment, such as a salad bar, where some designs have it directly above ready-to-eat salad ingredients; vents in that position directly increases the risk of contamination (FSIS, 2015). Fan units in refrigeration can mitigate the movement *L. monocytogenes.* Beading condensation that drips or blown is problematic

especially from an environmental surface that has been excessively soiled or dusty for an extended period. Gaskets that are damaged on refrigeration units allow warm air into the unit then causes condensation. The gaskets themselves or rubber seals can harbor *L. monocytogenes*. Defrost cycles on refrigeration units (as many as six times within a 24-hour period, depending upon the model) also have to be monitored and managed to avoid thermal abuse of products.

Designs of equipment in food processing areas also contribute to the harborage of *L. monocytogenes* if they cannot be easily cleaned and sanitized. Equipment should be easy to disassemble and re-assemble and food-processing layouts constructed with the task of efficient sanitation in mind (FDA, 2013). Beverage dispensers like deli slicers are a potential harborage area for *L. monocytogenes*, difficult to clean and often neglected to be properly cleaned and sanitized according to the manufactures directions. Biofilms can grow in the unrefrigerated interior tips of the spouts and tubing of the equipment and often found to have high microbial flora. (Lakshmanan & Schaffner, 2006). Closed food processing systems that rely on clean-in-place systems for large pieces of equipment that cannot be easily moved and enclosed areas of equipment like hollow rollers on conveyor belts, sheeters or other niche areas, are more difficult to clean and sanitize are more vulnerable to *L. monocytogenes* contamination. Biofilms can develop and present an environment for resident *L. monocytogenes* to establish and colonize (Tompkin, 2001). The design and equipment of a processing plant was studied over several years in Helsinki, Finland for the presence of *Listeria monocytogenes*. All areas were broken down into three compartments based on the product processed, design and type of equipment used. The results showed that compartment #1, was the most contaminated. Of the 2,540 samples taken in this area over a 6-year span, 171 isolates of *L. monocytogenes* were found (6.7%). Compartment #1 processed cooked meats and consisted of coolers, conveyors and packing machines. The

machines with poor design, complex structure and difficult to clean favored the persistence of *L. monocytogenes*. The contracted cleaning company that was assigned to compartment #1 was also noted as being delinquent, because samples were found to be positive after the cleaning and sanitizing process. The equipment in compartment #3 producing cooked ready to reheat meats, showed the least contamination. Of the 645 samples taken over the same 6-year period, one sample (0.2%) was positive for *L. monocytogenes*. This was due to better equipment design, more detailed cleaning and better compartmentalization, which facilitated a separation of processes. The structure of the processing lines promoted the eradication of *L. monocytogenes* (Keto-Timonen, *et al.*, 2007).

Listeria monocytogenes can grow as a biofilm on stainless steel, Teflon, glass, polypropylene, rubber nylon and polyester floor sealant and can be sanitizer resistant on glass, stainless steel and rubber. When tested in a trypticase soy broth, the biofilm formation grew greatest on polyester floor sealant, where 40% of the surface area was covered within 7 days of incubation. The biofilms are resistant to chlorine, iodine and quaternary ammonium sanitizers (Blackman & Frank, 1996). This is disconcerting for a retail food service processing environment, where a polyester floor sealant is used to fill cracks in an aged floor, stainless steel is the preferred material for food and non-food contact surfaces of equipment and quaternary ammonium sanitizer is widely used throughout the retail food industry. The hand sink pictured below in Figure 7 is a potential area for biofilm and is often neglected to be properly cleaned and sanitized on a routine basis in a retail food service.

Figure 7. Potential biofilm formation in hand sink stain.
Source: Image by David Walpuck

The efficacy of sodium hypochlorite used to sanitize vegetables was shown to be ineffective at eliminating *L. monocytogenes*. Biofilms increase the resistance of the bacteria to this chemical. A wax film on vegetables may also be detrimental to hypochlorite and actually inactivate it (Soriano, *et al.*, 2000).

Outside habitat factors should also be taken into consideration when understanding how *Listeria monocytogenes* can be introduced into the interior of a food processing facility. Individuals working in retail food service have a tendency to recognize the obvious inside the building, not the outside. Wet soil layers, urban development, temperature, proximity to forests, water and pasture, elevation, slope, soil pH and precipitation should be tested and measured to calculate presence and risk. Depth of a wet soil layer and proximity to water are two of the biggest factors in the survival of *L. monocytogenes*, while slope and gradient contribute to the spread of *Listeria monocytogenes* (Mwima, *et al*., 2017). More often than not, employees in the retail food service industry overlook the exterior environmental factors; such as the delivery truck, homeless encampments near the exterior of a facility, water runoff from a hill, a wooden pallet of product stored in mud outside or dust from a construction site as potential sources of contamination. Frequent presence of *L. monocytogenes* found in retail food service establishments correlate with the pathogen also found in nearby exterior environments. Retail

food operations have limited ability to prevent potential introduction of *L. monocytogenes* into food processing and storage areas (Saunders, et al., 2009).

Samples taken from natural environments (588) and produce production areas (734) in New York State showed the presence of *Listeria* spp. in 33% and 34% of the samples. Soil moisture, proximity to water and pasture showed high association to produce production areas, while elevation, study site and proximity to pastures showed a high association to natural environments. The data showed that *Listeria* spp. is present and prevalent in both agricultural and non-agricultural environments, suggesting a marker for potential *Listeria monocytogenes* contamination (Chapin *et. al*, 2014).

LISTERIOSIS

Listeria monocytogenes has been important in understanding cellular immune response, such as the inability of antibodies to defend against infections caused by intracellular pathogens. Immunology researchers since the 1960's have been interested in how *L. monocytogenes* can grow and survive in macrophages as an intercellular parasite (Vázquez-Boland, *et al.,* 2001).

People usually become ill with listeriosis after eating contaminated food. Listeriosis is an infection caused by the pathogen *Listeria monocytogenes*. Non-invasive listeriosis causes mild symptoms such as diarrhea and muscle aches, lasts only a few days and can be treated with over the counter medications. Listeriosis can become invasive where the pathogen can spread from the intestines to the blood stream and travels throughout the body and affects the central nervous system. This usually requires hospitalization with inpatient care and high dose antibiotics (FDA, 2017).

Forms of listeriosis:

- Listeriosis of the central nervous system- Most common infection involves meningitis, which is a frequently diagnosed infection. Symptoms include high fever, seizures and rigidity. Non-meningitic listeriosis is encephalitis involving the brainstem.
- Febrile gastroenteritis- Non-invasive and has common symptoms of vomiting, diarrhea and fever. This is the most common infection, but is the least diagnosed.
- Glandular listeriosis- Resembles mononucleosis (I contracted mononucleosis when I was in high school and can remember being very weak) with swelling of the salivary glands.
- Typhoid listeriosis- Typically affects immunocompromised people with a high fever.
- Atypical listeriosis- Rare. Symptoms include pneumonia, urethritis and abscesses.

- Local listeriosis- Causes papules and pustules on hands, feet, face and arms. Symptoms also include muscle aches, confusion, loss of balance, headache and fever (Public Health Agency of Canada, 2017).

Incubation Period

When listeriosis has spread past the human gut, it is invasive. The onset of symptoms has been reported as the same day in as little as 3 hours and as long as 70 days past exposure. Sometimes making the incubation period variable or a very long duration of time, potentially further complicating a foodborne illness investigation (CDC, 2017). This is especially true if the product is frozen and contaminated with *L. monocytogenes*. Consumers often think that a frozen product cannot cause a foodborne illness. This is when proper thawing procedures to prevent growth is extremely important.

At Risk Populations

The four groups of at risk populations for the disease include: 1) Very young children, where the immune system has yet to develop. 2) Pregnant or lactating women. A listeriosis infection with pregnant women can mean the potential of a miscarriage, stillbirth, premature delivery and life threatening issues with the infant. 3) The CDC estimates that individuals who are 65 years of age or older are 4 times more likely to contract a listeriosis infection, the reduction of stomach acids as the body ages decreases the ability to help fight disease. 4) Individuals with compromised immune systems (meaning people who already have a preexisting medical condition such as diabetes, alcoholism or cancer). (CDC, 2017).

Infective Dose

The infective dose of *Listeria monocytogenes* is difficult to determine and depends upon the strain, type of food involved and susceptibility of the host. In all likelihood, less than 1,000

cells will cause illness in immunocompromised individuals (FDA, 2017). Foods that have been implicated in listeriosis outbreaks contain >1,000 CFU/g or >1,000 CFU/ml of *L. monocytogenes* (Tompkin, 2001). The challenges involved in determining the dose-response relationship of *L. monocytogenes* are, the lack of an animal model, the long onset time of disease symptoms, which is a detriment to sample collection of implicated food, rarity of outbreaks and initial contamination levels. Illness onset from contaminated milkshakes in 2014, from four hospital patients in Kansas, determined that the contaminated product was distributed widely to the public with low levels of *Listeria monocytogenes*. The underlying compromised medical condition of the hospital patients infected with listeriosis was the biggest factor in the fatalities (Pouillot, *et al.,* 2016). It takes 10 to 100 million CFU to cause an infection of *Listeria monocytogenes* in healthy individuals and 0.1 to 10 million CFU in immune compromised individuals (Public Health Agency of Canada, 2017). Low doses of *L. monocytogenes* less than 10 million CFU ingested by healthy individuals from food products would have an inconsequential health effect, However, people who are undergoing a high dose steroid therapy for a medical condition would contract an infection from a low dose of *L. monocytogenes* (Golnazarian, *et al.*, 1989).

Carriers

Listeria monocytogenes can be found in a variety of hosts, including humans where it is estimated that 10% of the population can be carrying the pathogen in their gut and be asymptomatic (The Center for Food Security and Public Health-Iowa State University, 2005). Individuals working in dairy processing for several years are susceptible for hosting *L. monocytogenes*. Mammals, fish, crustaceans, insects and poultry (especially chicken) have also had *L. monocytogenes* isolated from them. The mode of transmission to humans is usually from ingesting contaminated food; however, there has been documented cases of veterinarians and

farmers contracting listeriosis from handling diseased animals, rare person-to-person transmission and pregnant mothers passing the disease to their unborn child (FDA, 2017).

The antibiotics used to treat *Listeria monocytogenes* infections include aminopenicillin, benzylpenicillin or a combination with aminoglycoside. *L. monocytogenes* is resistant to cephalosporins. A study done in Denmark on 229 patients, (median age 71 years) for antibiotic treatment and 30-day mortality that had *L. monocytogenes* bacteremia (172) and or meningitis (24), thirty-three had both. Cephalosporins was administered and accounted for 90% of inadequately treated cases. Antibiotic treatment was given to 195 patients, Benzylpenicillin (72), aminopenicillin (84), menopenem (28), sulfamethoxazole/trimethoprim 6 and piperacillin/tazobactam 5. Definitive treatment with benzylpenicillin and aminopenicillin resulted in a lower 30-day mortality (Thonnings, *et al.,* 2016).

OUTBREAKS/FOOD SOURCES

There are three scenarios leading to listeriosis illnesses. 1) Cases that are isolated, (sporadic listeriosis) and food products that are contaminated are seldom found. Due to a long onset of symptoms that expose a potential source. 2) A cluster of cases involving a single source of contaminated food that is mishandled and there is growth of *L. monocytogenes* before the product is consumed. Once the contaminated lot is identified and no longer on the market, the illnesses cease. 3) An outbreak of a virulent strain of *L. monocytogenes* that involves a few to several hundred individuals in different locations at different times from a long standing resident strain that contaminates multiple lots of food over weeks and months (Tompkin, 2001). Figure 8 depicts the timeline for a listeriosis outbreak.

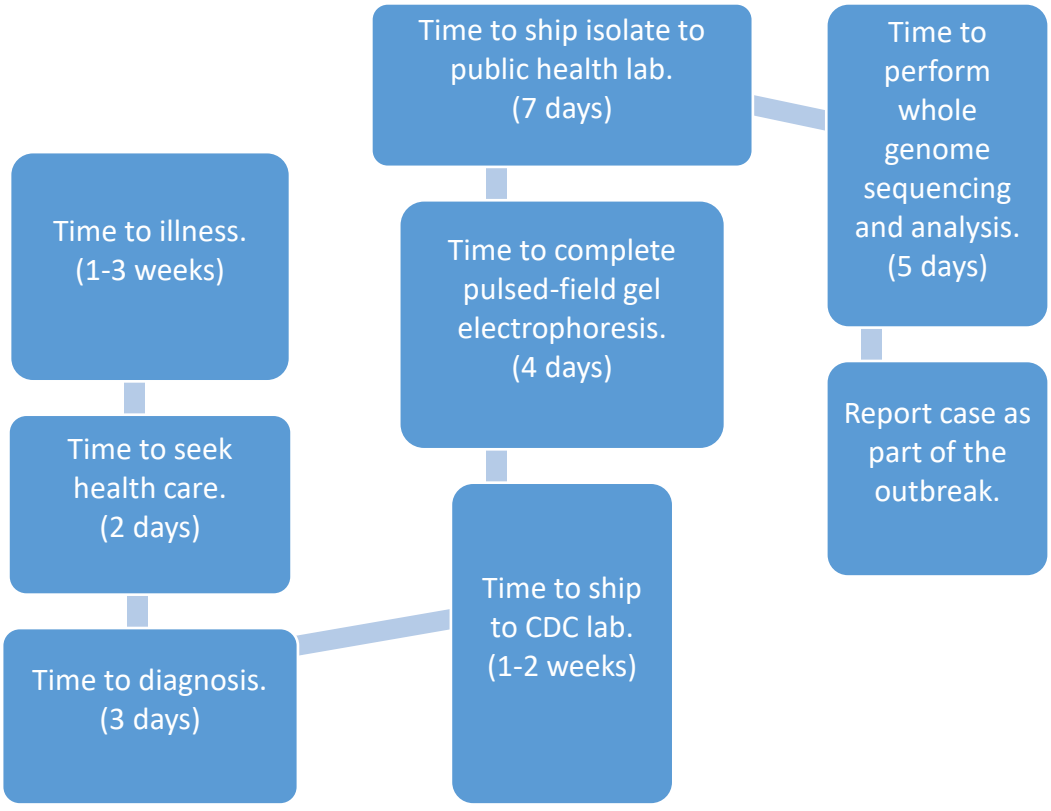

Figure 8. The timeline for a listeriosis outbreak typically takes between 2-10 weeks, or even longer. Cases can continue to increase and may have been linked years earlier. Source: CDC, 2016

The entire process takes time. In addition, if the source of the contamination is not disclosed publicly as soon as possible, there may be more victims of a foodborne illness outbreak. “Confidentiality” protects food manufactures and government officials from liability. Information becomes legal, plain and simple. State or local officials who want information from the FDA must be commissioned and understand that disclosing non-public information is criminal under Federal Law (21 U.S.C. 33 (j) and 18 U.S.C. 1905). The FDA may share non-public information with local and state officials if there is a written statement that the state agency has the authority to protect private confidential commercial information and not disclose it (the 20.88 agreement). Restricted information and trade secrets under the “Privacy act” may not be shared under the 20.88 agreement (FDA, 2016). Wrong accusations of contaminated products in the past have caused dramatic financial losses, such as the Mexican pepper *Salmonella* outbreak in 2008 that initially blamed tomatoes from the United States, costing the Florida and Georgia tomato industry $125 million dollars in lost revenue (Bloomberg Business News, 2014).

A foodborne illness outbreak is two or more people get sick and diagnosed from a common food source (FDA, 2013). Food sources of *L. monocytogenes* that have gotten people ill and caused fatalities include hot dogs, caramel apples, coleslaw, deli meat, ice cream, pasteurized and unpasteurized milk, raw and cooked meat and poultry products. The following lethal and well-published foodborne illness outbreaks involving listeriosis are case examples of how the contamination developed, involved three very different types of products, created public outcry, cost millions of dollars, caused massive recalls and illustrates negligence. One could argue that these outbreaks helped change industry standards in regards to food safety.

Unfortunately, like all foodborne illness outbreaks they could have been prevented with a proactive plan to specifically address *Listeria monocytogenes*.

The Jenson Farms *L. monocytogenes* outbreak ranks as one of the deadliest foodborne illness outbreaks in the history of the United States with 147 illnesses, 143 hospitalizations and 33 deaths across 28 states. The event caused the recall of millions of pounds of cantaloupes. It will be recognized as solidifying the fear of *Listeria monocytogenes* as an emerging pathogen throughout the food industry (CDC, 2012). The FDA identified the following factors as those that most likely contributed to the introduction, spread, and growth of *Listeria monocytogenes* in the cantaloupes: 1) A low level of *Listeria monocytogenes* was found in the field where the cantaloupes were grown and a truck used to transport cantaloupe to a cattle feeding pen was parked near the operation. Both scenarios could have been the original source and could have contaminated the interior of the facility. Once inside, the *L. monocytogenes* could colonize and become resident. 2) The packing facility's design allowed standing water on the floor near equipment and walkways and the floor was not easily cleanable due to the way it was constructed. 3) The packing equipment could not be easily cleaned and sanitized. 4) The washing and drying equipment used for cantaloupe packing was previously used for postharvest handling of another raw agricultural commodity. 5) There was no pre-cooling step to remove field heat from the cantaloupes before cold storage. As the cantaloupes cooled, there may have been condensation that promoted the growth of *Listeria monocytogenes* (FDA, 2011).

From September 13, 2013 to May 3, 2016, nine people were hospitalized across four states. They were stricken with listeriosis, traced back to CFR Frozen Food. Three of them died. Three hundred and fifty products under 42 brand names were recalled due to the outbreak, as well as 100 other products that used the recalled ingredients (CDC, 2016). The United States

Food and Drug Administration inspection report includes the following documented violations from CRF Frozen Foods of Pasco Washington: 1) A damaged plastic shovel used for food contact purposes. 2) Chipped, cracked and missing pieces of plastic on food contact portions of equipment on the onion production line. 3) A plastic conveyor belt with missing plastic pieces on at least five legs that were in direct contact with onions. 4) Knives used for cutting onions had employee initials etched on their blades. 5) Tape was used as a temporary repair on a cracked metal plate above a consumer pack line (FDA, 2016).

Ionizing radiation can kill *Listeria monocytogenes* from frozen vegetables, however the kind, size and uniformity of vegetable makes a difference in effectiveness. Frozen broccoli florets, lima beans, corn and green peas were examined and it was found that at -20°C, radiation does achieve a 5-log reduction in *L. monocytogenes.* The treatment did have an adverse quality effect and softened the peas and broccoli florets, but not the corn and lima beans (Niemira, *et al.*, 2002). For manufacturers, this would present a question of product quality verses microbial concerns based on irradiation or other food processing technologies.

Beginning in early March 2017. Several people became ill from *Listeria monocytogenes* associated with raw milk cheeses from Vulto Creamery of Walton New York. Eight people contracted invasive listeriosis and required hospitalization across four states, two of them died (CDC, 2017). Violations documented by the FDA inspectors were: 1) Employees had visible cuts on their arms reaching elbow-deep into vats of cheese to use their bare hands and arms to separate cheese curds. 2) Black and green mold on multiple pieces of equipment and surfaces in the facility. 3) Lack of temperature alarm systems for freezers, coolers and cheese storage rooms. 4) An admission by the owner that the company does not calibrate and never has calibrated the thermometers located in the cheese aging room and walk-in cooler. 5) Multiple plumbing

problems related to black flow prevention with drains. 6) Insect glue strips overloaded with dead flies. Vulto (the owner of the operation) was conducting regular swab tests of equipment and surfaces; there was more than 27 percent positive rate for *Listeria* species. This did not provoke him to conduct adequate follow-up testing after cleaning and sanitizing according to the inspection findings (FDA, 2017).

PREVENTION - RELEVANT TO A RETAIL FOOD SERVICE ENVIRONMENT

In keeping with the theme of the Food Safety Modernization Act, prevention or taking proactive measures against *L. monocytogenes* is a better alternative than being reactionary to a contamination issue. Being after the fact has its consequences.

The percentages in the below model Figure 9 were calculated and identified which ready-to-eat deli products were the biggest food safety threat and what food handling procedure would improve the safety of the product. A "Quality Risk Assessment" was used to interpret the data, which uses a mathematical model to create a virtual deli environment and links activities and practices to predictive consumer health outcomes involving illness associated with *Listeria monocytogenes* (FSIS, 2015).

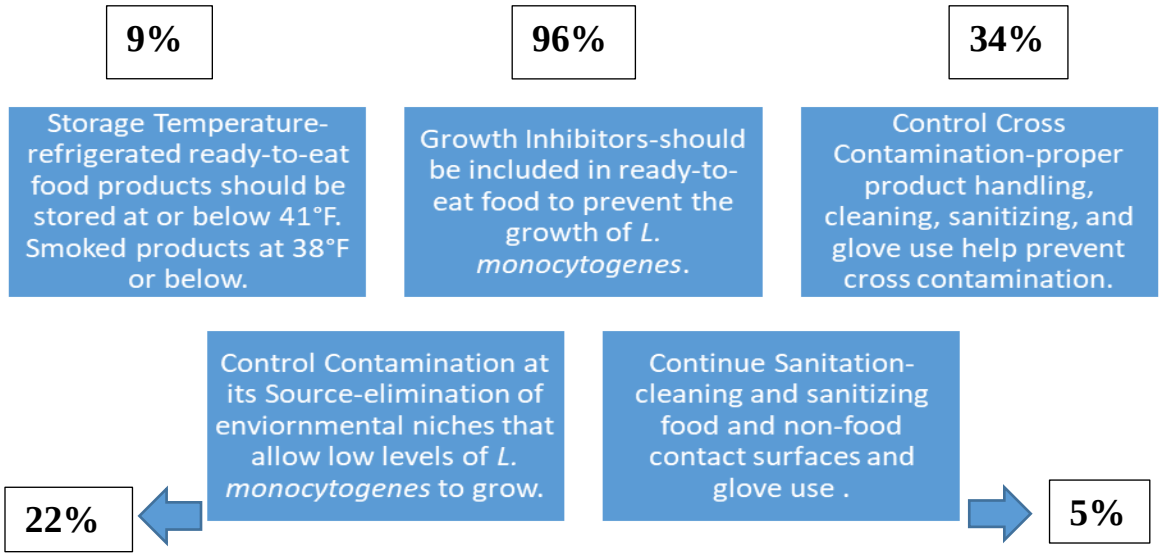

Figure 9. Estimated risk percentages of *L. moncytogenes* contamination in a retail deli environment.
Source: FSIS, 2015

Collaboration with vendors and associated business partners to retail food establishments should include the understanding and disclosure of the use of food antimicrobials. Growth inhibitors or "Food Antimicrobials" are used to inhibit spoilage, inactivate or limit the growth of

pathogenic microorganisms. They are broken down into two categories, traditional or naturally occurring. Traditional antimicrobials are compounds that need to be approved for use from the FDA. Naturally occurring antimicrobials come from plant, microbial or animal sources such as bacteriocins and proteins produced by lactic acid bacteria. Nisin, nitrates and lysozyme (traditional antimicrobials) are examples of food additive compounds used to control *C. botulinum* and other bacteria in the processing of cheese, hot dogs, cooked meat and poultry products, and cured meats (Davidson & Harrison, 2002).

Preservatives are used as a process control to prevent the growth of microorganisms. They inhibit enzymes, alter or destroy cell walls and membranes or denature protein. Commonly used preservatives to control *Listeria monocytogenes* are benzoates and sorbates (FDA, 2015).

Identification, elimination and control in Figure 10 is a three-step program to combat against the threat of *Listeria monocytogenes*.

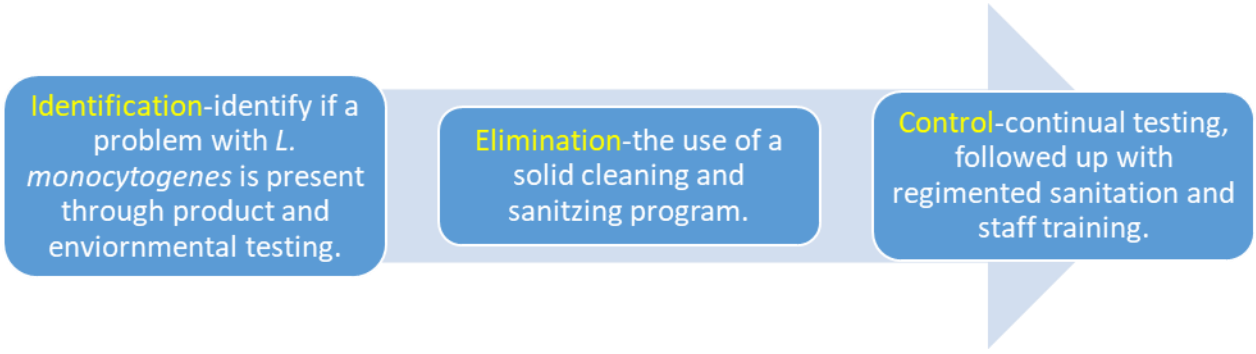

Figure10. Three steps to control *L. monocytogenes*.
Source: Food Manufacturing, 2016

Proper handwashing is vital aspect to personal hygiene in a food-processing environment. Hands of food handlers play an important role in the potential cross contamination of food, equipment and utensils. *Listeria monocytogenes* can survive up to 60 minutes on human fingertips when suspended in saline and longer when suspended in milk. Skin lipids and natural flora had no effect on the pathogen. Handwashing with soap or just hand sanitizer failed to

reduce 10 CFU of *L. monocytogenes* on fingertips when suspended in milk. Postproduction contamination of product is likely to blame, rather than the production process itself (Snelling, *et al*., 1991). Management of food processing establishments must realize that understanding and implementing proper handwashing is not a given, especially with food handlers that come from areas where food safety or hygiene is not a priority. Disposable gloves and outer clothing such as smocks, aprons or chef jackets can also be a source of contamination (Walpuck, 2016).

Sourcing food and ingredients from reputable and certified vendors is paramount to a strong food safety program. Vendors should operate under a Hazard Analysis Critical Control Point plan with routine product and equipment testing for the presence of pathogens and *Listeria monocytogenes*. Those vendors must follow Good Manufacturing Practices, Good Agricultural Practices or Good Retail Practices and be monitored by a professional, educated and credentialed food safety expert (not some underqualified carefree individual) that identifies potential biological, physical and chemical hazards (FDA, 2015). Food vendors making deliveries have to be held accountable for potential introduction of *L. monocytogenes* into a food facility. Using designated carts or U-boats to bring food directly in from the outside should be taken into consideration, restricted from entering a food processing or storage area, thoroughly cleaned, and sanitized.

Cleaning, Sanitizing and Other Preventive Measures

Proper cleaning and sanitizing food contact surfaces of equipment is vital in controlling *Listeria monocytogenes*. Sanitizers are used on clean surfaces, not to remove organic matter. Surfaces need to be scrubbed in detail during cleaning to help keep biofilms from formulating. Biofilms are hard to remove, especially with attached *L. monocytogenes* cells and can create a

resistance to sanitizers. *L. monocytogenes* cells that are in suspension are treated effectively with sanitizers and disinfectants (Crandall, *et al*., 2012).

Antimicrobial and sanitizer resistance of microorganisms have been found in aquatic environments, medical prosthetic devices, glass, stainless steel, rubber and polypropylene. Attached microorganisms in biofilms can contaminate contact surfaces of food equipment even after it has been treated with sanitizer before production. If *Listeria monocytogenes* were in a planktonic state (unattached to a surface) a 200-ppm quat sanitizer or 25-ppm iodophor sanitizer would have a 5-log reduction on *L. monocytogenes*. Nevertheless, if the cells were attached, even a contact time of 10 minutes on the sanitizers (quat and iodophor) would have little effect (Krysinski, *et al.,* 1992).

Quaternary ammonium chloride sanitizer (2.5 log reduction) was the most effective on stainless steel and aluminum when compared to Ethyl alcohol (.75-log reduction), alkyl dimethyl benzyl/ethyl benzyl ammonium chlorides (1.5 log reduction) and alkyl dimethyl benzyl ammonium chloride/isopropyl alcohol (1.5-log reduction) on attached *Listeria monocytogenes*. Wiping cloths (white bar towel and microfiber cloths) were tested against sanitizer wipes (1 log reduction alone) and it was determined that a white bar cloth soaked in quat sanitizer solution was the most effective combination (2.5 log reduction of *L. monocytogenes*). This is relevant because in a retail food service operation the trend is to use sanitizer wipes. The issue is that retail food service operators have a tendency to just use the wipes and neglect properly breaking down, cleaning and sanitizing equipment that is exposed to food (Crandall, *et al.,* 2012).

Rotation of sanitizers will better control the growth and resistance of *Listeria monocytogenes.* Quaternary ammonia to Chlorine based sanitizers will help control resistant biofilms (FSIS, 2015).

Cleaning utensils, brushes, mops, cloths and other aids will eventually become contaminated themselves from soiled environmental areas and equipment surfaces after continuous use. They can be a potential source and spread of pathogens, especially *L. monocytogenes*. Clean, and soak this equipment in clean sanitizer between uses in a janitorial sink or separate tub dedicated for that purpose (Food Manufacturing, 2006). Not a food preparation sink, like Figure 11 below.

Figure 11. Cleaning equipment soaking in food prep sink, which is a potential spread of contamination to food contact surfaces.
Source: Image by David Walpuck

Improper use of sanitizers is what leads to the microbial resistance. It is the lack of adequate contact time of sanitizers to a cleaned surface. Sub lethal levels of sanitizer and insufficient time of exposure to the microorganism when attached to a biofilm is the issue (Davidson & Harrison, 2002). In this case, there typically is a 30-second contact time (submersion) required for most quaternary ammonium sanitizers, as well as iodine sanitizers and sanitizing with hot water alone at 171°F. If the manufacturer's directions are not followed for the product and process, it will lose its effectiveness on microorganisms. The same is true if equipment is not properly cleaned, scrubbed and rinsed before sanitizing. It will lead to an ineffective result where the microbes are not reduced to an acceptable level (FDA, 2017).

Any temperature above 149°F (65°C) will be sufficient to kill *L. monocytogenes* (European Food Safety Authority, 2017). Heat treatments are a process control that is effective against *Listeria monocytogenes*. Heat treatments 158°F to 212°F will kill vegetative bacteria. The product will not be shelf stable. Cooking examples include, baking, frying, boiling, steaming and roasting. Periodic checking of temperature will not validate that all parts of the product is cooked to an appropriate internal temperature, therefore it is important to scientifically study the minimum and maximum values of time, temperature and size of the item being cooked (FDA, 2015).

Preventive measures to control contamination of *Listeria monocytogenes* have included equipment (dicers and slicers) being broken down, cleaned, sanitized then put into an oven. Alternatively, a tarp put over equipment, injected with steam after cleaning, and before sanitizing. (Tompkin, 2001). The steam or dry heat in these strategies along with a proper cleaning and sanitizing process would be sufficient to kill any existing *L. monocytogenes.* Both of these techniques are of great significance. I will investigate further and implement in our retail grocery stores.

Temperature logs, sanitizer logs and cleaning schedules in Figure 12 are documents that should be maintained to control sanitation and minimize the potential of contamination. All should include dates, times and signatures of parties involved. Logs and schedules should be updated routinely (daily for Temperature and Sanitizer Logs and weekly for cleaning schedules) and verified by food service operators. They are legal documents in a court of law (Walpuck, 2015)

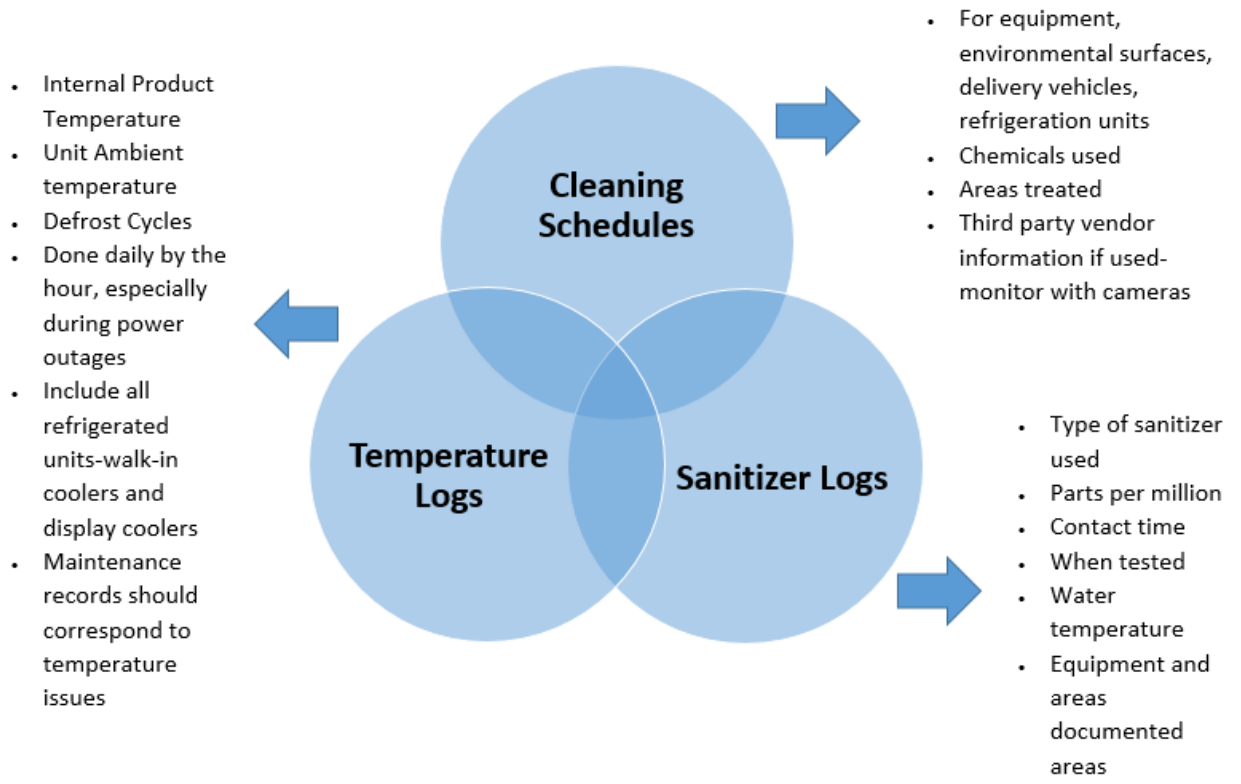

Figure 12. Types of logs to document compliance.
Source: David Walpuck

Direct acidification of food, where measured amounts of acid are added to low acid foods after processing is another measure to control microbial growth. Gram-positive bacteria such as *L. monocytogenes* require a pH range of 4.0-8.5 for growth. (FDA, 2015). There are many foods outside of this pH range, especially those that are mainly alkaline (melons, sprouts & lettuce) or acidic (beef, pork & goat cheese). Foods that are potentially hazardous or need proper time and temperature control for safety include cut melons, cut lettuce, beef and raw seed sprouts (FDA, 2015).

Surveillance

For the past 30 years, the CDC has used surveillance to understand *Listeria* infections in the United States.

The *Listeria* Initiative - National program that collects information on listeriosis cases. State and local health departments report case information back to the CDC for analysis.

Foodborne Disease Active Surveillance Network - Tracks trending listeriosis infections through food and monitors incidence and how illness occurs.

National Notifiable Disease Surveillance System - Collaboration of all levels of regulatory agencies involved with public health to share notifiable illnesses using case definitions. Summarizes data weekly and annually.

PulseNet - Run by the CDC and developed in 1996. Shares Pulsed Field Gel Electrophoresis and Whole Genome Sequencing results from public health laboratories. Matches genetic fingerprints of pathogens. There are 83 laboratories in the United States that are in the PulseNet network that are tasked to find the source of a foodborne illness outbreak, alert the public to the emergency and identify food safety issues.

Foodborne Disease Outbreak Surveillance System - Collects information on foodborne disease outbreaks and the impact on public health. Publishes annual statistics of foodborne disease in the U.S (CDC, 2016).

Retail grocery stores in the state of New York are constantly monitored for food safety and food fraud compliance from the New York State of Agriculture and Markets. At any time, products and equipment can be tested for the potential presence of pathogens and product ingredients. Governor Andrew Cuomo from New York State announced in a press release dated 2/24/17 the increase in food and beverage testing for pathogens, purity and label accuracy. Sixty seven thousand lab samples were collected in 2016, up 10% from 2015 resulting in more than 300 Class 1 recalls across New York State. (New York Office of the Governor, 2017) Product safety and protecting consumers against fraud are the main drivers behind this initiative. The

supermarket cooperative I work for has seen the increase in sampling first hand, not only from manufactured products and produce, but from store made food as well. Items such as store made chicken, anti-pasta and seafood salads, sliced deli meats, sprouts, coleslaw mix, cakes and cookies have all been collected for testing. Not only have products been tested, food contact surfaces have also been swabbed by inspectors from New York State Department of Agriculture and Markets. A presumptive positive test for *Listeria* spp. is cause for concern. It can mean the potential for *L. monocytogenes*, a food recall, increased cleaning and sanitizing, an interruption of food processing operations and an increased surveillance initiative/visitation from regulatory authorities. More often than not, there will be another test for *Listeria monocytogenes* on a future surveillance follow up. Clean is not just clean, contact and non-contact surfaces of equipment and environmental surfaces have to be safe from dangerous microbial growth. A disadvantage of product testing is that a positive test will not determine a source of contamination, nor will it prevent future *L. monocytogenes* occurrences. Sources would be difficult to detect, especially if equipment used in product processing was not in use at the time of sampling (Tompkin, 2001).

Cameras in the retail food service environment are a type of surveillance and can be used to monitor loss prevention, food safety and customer service. They need to be operational to be effective. The footage can be subpoenaed in a court of law if an individual gets ill or injured from consuming food.

EDUCATION

The internet is a main source of food safety information. It is estimated that 72% of young adults are accessing health related information online. Social media, either Facebook or other sites when used as a platform to improve food safety knowledge was found in to be a favorable method of communication to college students. In a survey consisting of college students broken down into focus groups with comparable educational majors, work experience and memberships in clubs; found when asked about the format of food safety information via social media, 36.9% of students polled enjoyed learning about food safety from a social media platform (Mayer & Harrison, 2012).

Part of understanding the risk of *Listeria monocytogenes* starts with the availability of training and other educational materials, not only for people involved in the food industry, but also for the consumer. If the information and prevention is not formalized to food handlers in the retail industry, part of a routine, job description or a general interest, it may take a tragic incident of listeriosis to bring the pathogen into the realm of concern.

A Class 1 recall of a potentially deadly product in someone's freezer that they saw on the news, may bring a reaction, however there will always be individuals who ignore the warning or attempt make a profit and radicalize the situation. Like, selling potentially *L. monocytogenes* contaminated half-eaten containers of Blue Bell Cream on Craigslist for $10,000 (Siegner, 2015).

A study done on consumers regarding food safety knowledge and practices revealed that out of 1,620 people polled, only 9.6% were aware of the pathogen *Listeria monocytogenes* and 1.1% knew of the foods that could cause listeriosis. On the other hand, 80.2% knew about *Salmonella* and 53.7% were aware of the foods that caused the infection. Even though this study

was done in 1996, it still highlights the lack of understanding of *L. monocytogenes*. That translates into the retail food service industry by way of an uneducated pool of food handlers entering a work environment that comes from a consumer base (Altekruse, *et al.,* 1996).

Consumer knowledge and fear about *L. monocytogenes* shifted dramatically years later in the 4 weeks beginning October 9, 2011 surrounding the Jenson Farms Cantaloupe *Listeria monocytogenes* outbreak. During that time, when the news hit about the listeriosis cases involved with cantaloupe, prices for the product were 6.2 million dollars below normal and there was a 3.9 million dollar reduction in cantaloupe sales due to the lack of demand (United States Department of Agriculture Economic Research Service, 2015). Suggesting that the market conditions and consumers knew what *L. monocytogenes* was and reacted to the warnings from regulatory agencies to avoid consuming cantaloupes, whether they were the contaminated product or not.

As a person who teaches food safety to food handlers in a structured classroom environment, it is always important to choose the appropriate communication style, include real stories of contaminated product and the consequences as case examples, especially if it involves an eye opening result of a small child losing their life. Severity must be disclosed in a manner that will make an individual pay attention. Education about *Listeria moncytogenes* for the food industry must extend out of the classroom and web based training into the retail food environment. Physically showing and describing the potential risk of *L. monocytogenes* such as, smoked salmon on display at 52°F. An ice shovel used to pick up garbage off an excessively soiled floor. Dust from a fan unit blowing on cooked chicken that is cooling uncovered in the walk-in cooler. This real time scenario has a more “hands on” effect for training; it is not just some mundane information from a textbook or computer screen.

The CDC has a wealth of food safety educational resources on their website, not only for individuals in the food industry, but for the consumer as well. Everything from fact sheets, tips on food handling videos, at risk populations and links to other informative websites, even in other languages as well. (CDC, 2013)

IMPACT ON THE RETAIL FOOD INDUSTRY

Globalization of food safety risks, widespread travel, more imported food, increasing populations, emerging pathogens and more ready-to-eat food choices have had a dramatic impact on the retail food industry. There are many reasons to handle and sell food safely: 1) financial loss from lack of business, food recalls, disposal, fines, legal costs. 2) maintain reputation, consumer confidence and loyalty. 3) compliance with regulatory agencies. 4) ensure a safe food supply. 5) increase sales and profitability (Hussain & Dawson, 2013).

Other detrimental impacts *L. monocytogenes* has on retail foodservice operators is the negative publicity and loss of sales in association with the shutdown of processing areas from regulatory agencies. If there is testing done at a retail site and *L. monocytogenes* (even presumptively) is found on an environmental surface or in a product sold at the business, the regulatory agency has the authority to protect public health and close the affected area. This means a financial loss from the business and the extra costs associated with increased detailed cleaning (usually from a professional third party that will not be cheap) and professional lab testing. If the incident goes public, such as the article posted in Food Safety News titled "Stop and Shop Deli Customers at Risk for *Listeria* Infection" (Beach, 2018), there will not only be public discontent, Stop and Shop will also be a target of health regulators in other locations, potentially in other states as well. Bad news travels fast these days and social media can be relentless. In the case of Stop and Shop, who is a direct competitor to our grocery stores, the article was a warning shot that resonated with our executive committee and operations staff. The story was lit like a lantern, about compromised deli slicer contact surfaces. A consumer warning was issued with instructions to discard any deli meats and cheeses purchased from the store and to thoroughly clean and sanitize refrigerators at home (Beach, 2018). This example circulated

around our company the morning the story was published. I felt like Paul Revere, the original ardent monitor for the Committee of Safety. One by land, two by sea. The action taken by the Rhode Island Department of Health verified the regulatory "winds of change" regarding *Listeria monocytogenes* in the Northeastern part of the United States.

Collateral damage from foodborne illness outbreaks and associated food recalls can severely affect business partners of implicated entities. An example, such as the 2009 *Salmonella* outbreak involving the Peanut Corporation of America that was responsible for over 700 infections and 9 deaths, also affected Kellogg of Battle Creek Michigan who used Peanut Corporation of America's contaminated peanut ingredients to make their products. Kellogg reported losing up to $70 million dollars in recall related lost revenue. *Listeria monocytogenes* contamination or potential contamination is a cause for a Class 1 recall with food products (Hussain & Dawson, 2013). Vendors and associated food partners need to be responsible for the safety of their products.

CONCLUSION

Ready-to-eat foods in retail food service operations are a constant threat of contamination from *Listeria monocytogenes*. Its distinctive growth in refrigerated and frozen temperatures, ability to survive in a variety of environmental conditions for years and a high mortality rate for immunocompromised individuals, makes the pathogen a clear-cut concern. A zero tolerance policy from regulatory agencies recognizes *L. monocytogenes* as a threat to public health, for its presumptive existence in food products, surfaces of equipment and environmental niche areas in a retail food processing area. **Operators of retail food service establishments need to have a specific operating plan to prevent *L. monocytogenes* contamination**. Any program, no matter what industry, requires adequate funding. This only happens when everyone in the executive staff agrees that there is a value and a need. In this case, proper financial resources are needed to protect the brand. That is value, because the consequences of a foodborne illness outbreak could devastate a retail food business and preventive measures will cost less. The need is compliance with regulatory laws and positive consumer confidence. The *L. monocytogenes* control plan will include the following important parameters:

- A detailed cleaning and sanitizing program to include equipment, environmental areas and an aggressive weekly drain-cleaning program. Rotation of sanitizers on a monthly basis. Triple sinks and dishwashers will be retrofitted with appropriate chemical dispensing equipment for both quat and chlorine based sanitizer solutions. Use of steam cleaning on hard to clean food contact surfaces of equipment. Detailed cleaning of processing areas by a third party cleaning company. Each location will have a designated management employee to oversee, monitor and delegate cleaning and sanitizing principles regarding the *L. monocytogenes* control plan.

Each month they will be responsible to summarize log documentation, activities related to third party cleaning, chemical usage and weekly drain cleaning.

- Review of equipment design that is not easily cleanable, especially those that directly contact food such as deli slicers, auto deli slicers and cheese graters. Equipment will be replaced that cannot be easily taken apart to better expose surfaces to detergents and sanitizers to limit potential *L. monocytogenes* biofilm formation. Food processing areas also assessed for design and use regarding potential contamination. Compartmentalization and food handling tasks segregated to eliminate cross contamination in ready-to-eat food processing areas.
- Log documentation is a critical standard operating procedure to make sure food safety protocols are followed to reduce the potential contamination of *L. monocytogenes*. Cleaning schedules, sanitizer logs, temperature logs, cooking logs and preventive maintenance schedules diligently maintained and followed up by both operations and field management. All log documentation will be kept on file for 90 days and are legal documents in a court of law. Their documentation or lack thereof, paints a picture of compliance or non-compliance.
- Assessments of potential introduction of *L. monocytogenes* from exterior environment factors, vendor deliveries and employee areas reviewed on a monthly basis. Designated carts and U-boats will not be permitted to enter food processing areas and be thoroughly cleaned and sanitized and documented on a cleaning schedule
- An environmental monitoring program instituted to test processing areas for the presumptive presence of *L. monocytogenes* on a weekly basis. Results will be monitored and corrective actions taken for non-compliance.

- Surveillance footage from cameras in food preparation areas routinely reviewed for food safety measures and control of *L. monocytogenes*. Especially after an event such as a third party cleaning or drain back up.
- Enhanced training on *L. monocytogenes* both at the retail level and food safety certification class.
- Networking with regulatory agencies and food industry groups to share compliance initiatives will also be a part of the targeted plan.

The cost associated with product recalls, loss of sales, damaged reputation, product and environmental testing, lawsuits and litigation can make a retail food service business a mere memory.

Presently, South Africa is experiencing the largest foodborne illness outbreak involving *Listeria monocytogenes* in the history of the world. So far, there has been 180 deaths and over 1,000 listeriosis infections from contaminated polony, a ready-to-eat meat substitute product that is only partially cooked during processing (CDC, 2018).

Believe “The Hype”…

REFERENCES

Altekruse, S., Street, D., Fein, S., Levy, A. (1996). Consumer Knowledge of Foodborne Microbial Hazards and Food Handling Practices. *Journal of Food Protection*. Vol. 59, No. 3, Pages 287-294. https://doi.org/10.4315/0362-028X-59.3.287

Beach, C. (2018, February). Stop and Shop Deli Customers at Risk for Listeria Infection. *Food Safety News.* Retrieved from: http://www.foodsafetynews.com/2018/02/stop-shop-deli-customers-at-risk-for-listeria-infection/#.WoG72rpFzIU

Berrang, M., Frank, J. (2012). Generation of Airborne *Listeria innocua* from Model Floor Drains. *Journal of Food Protection*. Vol. 75. No. 7, Pages 1328-1331. doi: 10.4315/0362-028X.JFP-12-021

Blackman, I., Frank, J. (1996). Growth of *Listeria monocytogenes* as a Biofilm on Various Food-Processing Surfaces. *Journal of Food Protection*. Vol. 59, No. 8, Pages 827-831. https://doi.org/10.4315/0362-028X-59.8.827

Borucki, M., Call, D. (2003). *Listeria monocytogenes* Serotype Identification by PCR. *Journal of Clinical Microbiology*. Pages 5537-5540. doi: 10.1128/JCM.41.12.5537-5540.2003

Centers for Disease Control and Prevention. (2017, June 29). *Listeria (Listeriosis*). Retrieved from: https://www.cdc.gov/listeria/

Centers for Disease Control and Prevention (2018) *Listeriosis in South Africa*. Retrieved from: https://wwwnc.cdc.gov/travel/notices/alert/listeriosis-south-africa

Centers for Disease Control and Prevention (2016, July 15). *Multistate Outbreak of Listeriosis Linked to Frozen Vegetables. (Final Update)*. Retrieved from: https://www.cdc.gov/listeria/outbreaks/frozen-vegetables-05-16/index.html

Centers for Disease Control and Prevention (2017, May 3). *Multistate Outbreak of Listeriosis Linked to Soft Raw Milk Cheese Made by Vulto Creamery (Final Update)*. Retrieved from: https://www.cdc.gov/listeria/outbreaks/soft-cheese-03-17/index.html

Centers for Disease Control and Prevention. (2012, August 27). *Multistate Outbreak of Listeriosis Linked to Whole Cantaloupes from Jensen Farms, Colorado (Final Update)*. Retrieved from: https://www.cdc.gov/listeria/outbreaks/cantaloupes-jensen-farms/index.html

Centers for Disease Control and Prevention (2017, June 29). *Surveillance*. Retrieved from: https://www.cdc.gov/listeria/surveillance.html

Centers for Disease Control and Prevention (2016, April 18). *Surveillance and Data Systems*. Retrieved from: https://www.cdc.gov/ncezid/dfwed/keyprograms/surveillance.html

Centers for Disease Control and Prevention (2016, December 12). *Timeline for Linking a Case of Listeria Infection to an Outbreak*. Retrieved from: https://www.cdc.gov/listeria/timeline.html

Chapin, T., Nightingale, K., Worobo, R., Weidmann, M., Strawn, L. (2014). Geographical and Meteorological Factors Associated With Isolation of *Listeria* Species in New York Produce Production Environments, *Journal of Food Protection*, Vol. 77, No. 11, Pages 1919-1928. http://doi.org/10.4315/0362-028X.JFP-14-132

Crandall, P., O'bryan, C., Martin, E., Kuefner, M., Pendleton, S., Shannon, E., Marcy, J., Ricke S. (2012). Efficacy of Cleaning and Sanitizing Agents Against Attached *Listeria monocytogenes* on Meat Slicer Components. *Food Protection Trends*. Vol. 32, No. 2, Pages 68-72. https://www.foodprotection.org/files/food-protection-trends/Feb-12-Crandall.pdf

Davidson, P., Harrison, M. (2002). Resistance and Adaption to Food Antimicrobials, Sanitizers and Other Process Controls. *Food Technology*. Vol. 56. http://ift.org/~/media/Knowledge%20Center/Science%20Reports/Scientific%20Status%20Summaries/resistanceantimicrobials_1102.pdf

Doyle, M. (2001) Virulence Characteristics of *Listeria monocytogenes*. *FRI Briefings*. Food Research Institute University of Wisconsin-Madison. Retrieved from the University of Wisconsin-Madison website: https://fri.wisc.edu/docs/pdf/virulence/mono.pdf

Eklund, M., Poysky, R., Paranjpye, R., Lashbrook, L., Peterson, M., Pelroy, G. (1994). Incidence of *Listeria monocytogenes* in Cold-Smoked Fishery Products and Processing Plants. *Journal of Food Protection*. Vo. 58, No.5, Pages 502-508. https://doi.org/10.4315/0362-028X-58.5.502

European Food Safety Authority (2017) *Listeria*. Retrieved from: https://www.efsa.europa.eu/en/topics/topic/listeria

Farber J., Sanders G., Johnston M. (1989). A Survey of Various Foods for the Presence of Listeria Species. *Journal of Food Protection*. Vol. 52, No, 7, Pages 456-458. https://doi.org/10.4315/0362-028X-52.7.456

Gombas, D., Chen, Y., Clavero, R., Scott, V. (2002). Survey of *Listeria monocytogenes* in Ready-to-Eat Foods. *Journal of Food Protection*. Vol. 66, No. 4, Pages 559-569. https://doi.org/10.4315/0362-0362-028X-66.4.559

Grinstead, D. (2006, December 11). Fighting Food Manufacturing Fears: How to Control and Eliminate Listeria. *Food Safety Magazine*. Retrieved from: https://www.foodmanufacturing.com/article/2006/12/fighting-food-manufacturing-fears-how-control-eliminate-listeria

Hussain, M., Dawson, C. (2013). Economic Impact of Food Safety Outbreaks on Food Businesses. *Foods*. Department of Wine, Food and Molecular Sciences, Lincoln University, New Zealand. Pages 585-589. https://doi.org10.3390/foods2040585

Kaferstein, F., Motarjemi, Y., Bettcher, W. (1997). Foodborne Disease Control: A Transnational Challenge. *Emerging Infectious Diseases (Special Issue).* Vol 3, No 4, doi:10.3201/eid0304.970414

Kathariou, S. (2002). *Listeria monocytogenes* Virulence and Pathogenicity, a Food Safety Perspective. *Journal of Food Protection*. Vol. 65, No. 11, Pages 1811-1829. https://doi.org/10.4315/0362-028X-65.11.1811

Keto-Timonen, R., Tolvanen, R., Lunden, J., Korkeala, H. (2007). An 8-Year Surveillance of the Diversity and Persistance of *Listeria monocytogenes* in a Chilled Food Processing Plant Analyzed by Amplified Fragment Length Polymorphism. *Journal of Food Protection*, Vol. 70, No. 8, Pages 1866-1871. https://doi.org/10.4315/0362-028X-55.4.246

Krysinski, E., Brown, L., Marchisello, T. (1992). Effect of Cleaners and Sanitizers on *Listeria monocytogenes* Attached to Product Contact Surfaces. *Journal of Food Protection*. Vol. 55, No. 4, Pages-246-251. https://doi.org/10.4315/0362-028X-55.4.246

Lakshmanan C., Schaffner, D. (2006). Understanding and Controlling Microbiological Contamination of Beverage Dispensers in University Foodservice Operations. *Food Protection Trends*. Vol. 26, No. 1, Pages 27-31.

Lyautey, E., Lapen, D., Topp, E. (2007), Distribution and Characteristics of *Listeria monocytogenes* Isolates from Surface Waters of South Nation River Watershed, Ontario, Canada. *Applied and Environmental Microbiology* (73) 5401-5410. doi: 10.1128/AEM.00354-07

Mayer, A., Harrison, J. (2012). Safe Eats: An Evaluation of the Use of Social Media for Food Safety Education. *Journal of Food Protection*, Vol. 75, No. 8, Pages 1453-1462. https://doi.org/104315/0362-028X.11-551

Mwima, R., Gidudu, A., Mazimwe, A., Ligmann-Zielinska, A., Majalija, S., Khaitsa, M., Kabasa, J., Bergholz, P. (2017). Spatially explicit uncertainty modeling of zoonotic pathogen distribution: a case of *Listeria monocytogenes* in New York State, USA. *Applied Geomatics*. Vol 9, Issue 1, Pages 27-41. doi: 10.1007/s12518-016-0177-4

New York State Office of the Governor. (2017). Food Laboratory Consumer Protection Actions. (Press Release). Albany, NY. https://www.governor.ny.gov/news/governor-como-announces-results-new-york-state-food-laboratory-consumer-protection-actions

Nicholson-Kramer, G. (2016). Safe Food: A Product of a Clean Environment. *Food Safety Tech.* Retrieved from the Food Safety Tech website: https://foodsafetytech.com/feature_atrticle/safe-food-a-product-of-a-clean-enviornment/

Niemira, B., Fan, X., Sommers, C. (2002). Irradiation Temperature Influences Product Quality Factors of Frozen Vegetables and Radiation Sensitivity of Inoculated *Listeria monocytogenes*. *Journal of Food Protection*. Vol. 65, No. 9, Pages 1406-1410. https://doi.org/10.4315/0362-028X-65.9.1406

Pouillot, R., Klontz, K., Chen, Y., Burall, L., Macarision, D., Doyle, M., Bally, K., Strain, E., Datta, A., Hammack, T., Doren, J. (2016). Infectious Dose of *Listeria monocytogenes* in Outbreak Linked to Ice Cream, United States 2015. *Emerging Infectious Diseases*. Retrieved from: https://wwwnc.cdc.gov/eid/article/22/12/16-0165_article doi:10.3201/eid2212.160165

Public Health Agency of Canada (2017*). Pathogen Safety Data Sheets: Infectious Substances-Listeria monocytogenes*. Retrieved from: https://www.canada.ca/en/public-health/services/laboratory-biosafety-biosecurity/pathogen-safety-data-sheets-risk-assessment/listeria-monocytogenes.html

Ridenhour, C., Sadler, E. & Shocklee, H. (1988). Don't Believe the Hype. New York: Missing Link Music.

Saunders, B., Sanchez, M., Rice, D., Corby, J., Stich, S., Fortes, E., Roof, S., Wiedmann, M. (2009). Prevalence and Molecular Diversity of *Listeria monocytogenes* in Retail Establishments. *Journal of Food Protection*. Vol. 72, No. 11, Pages 2337-2349. https://doi.org/10.4315/0362-028X-72.11.2337

Soriano, J., Rico, H., Molto, J., Manes J. (2000). *Listeria* Species in Raw and Ready-to-Eat Foods from Restaurants. *Journal of Food Protection*. Vol. 64, No. 4, Pages 551-553. https://doi.org/10.4315/0362-028X-64.4.551

Shantha, S., Gopal, S. (2013). Incidence of Listeria Species in Food and Food Processing Environment: A Review. *Journal of Microbiology and Biotechnology*. Vol 3, Issue 1, Pages 1-8. https://www.rroij.com/open-access/incidence-of-listeria-species-in-food-and-food-processing-environment-a-review.php?aid=34488

Siegner, C. (2015, May 13) Online Hawkers Try to Sell Blue Bell Ice Cream Despite Recall. *Food Safety News*. Retrieved from: http://www.foodsafetynews.com/2015/05/online-hawkers-try-to-sell-blue-bell-ice-cream-following-recall/#.Wlep8uRy7IU

Snelling, A., Kerr, K., Heritage, J. (1991). The Survival of *Listeria monocytogenes* on Fingertips and Factors Affecting Elimination of the Organism by Hand Washing and Disinfection.

Journal of Food Protection. Vol, 54, No 5, Pages 343-348. https://doi.org/10.4315/0362-028X-54.5.343

The Center for Food Security and Public Health-Iowa State University (2005). *Listeriosis*. Retrieved from: http://www.cfsph.iastate.edu/Factsheets/pdfs/listeriosis.pdf

Thonnings, S., Knudsen, J., Schonheyder, H., Sogaard, M., Arpi, M., Gradel, K., Ostergaard, C. (2016), Antibiotic Treatment and Mortality in Patients with *Listeria monocytogenes* Meningitis or Bacteraemia. *Clinical Microbiology and Infection.* 22, Pages 725-730. https://doi.org/10.1016/j.cmi.2016.06.006

Tompkin, R. (2001). Control of *Listeria monocytogenes* in the Food-Processing Environment. *Journal of Food Protection.* Vol. 65, No. 4, Pages-709-725. https://doi.org/10.4315/0362-028X-65.4.709

United States Department of Agriculture Economic Research Service (August 2015). *Consumers Behaved Rationally, If Belatedly, After Food Safety Recalls in 2011 and 2012*. Retrieved from: https://www.ers.usda.gov/amber-waves/2016/januaryfebruary/consumers-behaved-rationally-if-belatedly-after-food-safety-recalls-in-2011-and-2012/

United States Department of Agriculture Food Safety and Inspection Service (2015, June*). FSIS Best Practices Guidance for Controlling Listeria monocytogenes (Lm) in Retail Delicatessens June 2015*. Retrieved from: https://www.fsis.usda.gov/wps/wcm/connect/29d51258-0651-469b-99b8-e986baee8a54/Controlling-LM-Delicatessens.pdf?MOD=AJPERES

United States Food and Drug Administration. (2017, October 24*). Bad Bug Book (Second Edition) Foodborne Pathogenic Microorganisms and Natural Toxins Handbook.*

Retrieved from: https://www.fda.gov/Food/FoodborneIllnessContaminants/CausesOfIllnessBadBugBook/

United States Food and Drug Administration. (2011, December 15). *Environmental Assessment (EA) conducted at Jensen Farms (FEI: 3008442043) on September 22-23, 2011*. Retrieved from: https://www.fda.gov/downloads/AboutFDA/CentersOffices/OfficeofGlobalRegulatoryOperationsandPolicy/ORA/ORAElectronicReadingRoom/UCM291076.pdf

United States Food and Drug Administration. (2016, July 15). *FDA Investigated Listeria Outbreak Linked to Frozen Vegetables*. Retrieved from: https://www.fda.gov/Food/RecallsOutbreaksEmergencies/Outbreaks/ucm499157.htm

United States Food and Drug Administration (2018, January 24). *Food Code*. Retrieved from:https://www.fda.gov/food/guidanceregulation/retailfoodprotection/foodcode/default.htm

United States Food and Drug Administration (2015). *Hazard Analysis and Risk Based Preventive Controls for Human Food: Draft Guidance for Industry*. Retrieved from: https://www.fda.gov/downloads/Food/GuidanceRegulation/FSMA/UCM517399.pdf

United States Food and Drug Administration. (2017, February 28). *Inspection Observations Vulto Creamery LLC.* Retrieved from: https://www.fda.gov/ucm/groups/fdagov-public/@fdagov-afda-orgs/documents/document/ucm554717.pdf

United States Food and Drug Administration (2016, May 2). *Regulatory Procedures Manual 3-6 Confidentiality*. Retrieved from: https://www.fda.gov/ICECI/ComplianceManuals/RegulatoryProceduresManual/ucm176719.htm

Vázquez-Boland, J., Kuhn, M., Berche, P., Chakraborty, T., Domínguez-Bernal, G., Goebel, W., Bruno González-Zorn, B., Wehland, J., Kreft, J. (2001). Listeria Pathogenesis and Molecular Virulence Determinants. *Clinical Microbiology Reviews*, 14, (3), Pages 584-640. https://ncbi.nlm.nih.gov/pmc/articles/PMC88991/

Walpuck, D. (February/March 2016). Employee Hygiene and Handwashing in Retail Food Service Establishments. *Food Safety Magazine*. Retrieved from: https://www.foodsafetymagazine.com/magazine-archive1/februarymarch-2016/employee-hygiene-and-handwashing-in-retail-foodservice-establishments/

Walpuck, D. (2015, February 24). Temperature Logs: A Misunderstood Liability. *Food Safety News*. Retrieved from: http://www.foodsafetynews.com/2015/02/temperature-logs-a-misunderstood-liability/#.WnMQGuRy7IU

Wong, V., (2014, September 29). Rotten Tomatoes: Farmers Pay the Price for a False Food-Safety Warning. *Bloomberg Business News*. Retrieved from: https://www.bloomberg.com/news/artricles/2014-09-29/tomato-farmers-pay-the-price-for-fdas-false-salmonella-warning