Chapter 5
Listeria monocytogenes, Listeriosis and Control Strategies: What the Retail Deli and Food Safety Manager Need to Know

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5.1 Introduction to *Listeria* spp., *L. monocytogenes*, and Listeriosis

5.1.1 Overview of Listeria *Species*

Listeria is a bacterial genus with 10 recognized species which include *L. monocytogenes*, *L. welshimeri*, *L. grayi*, *L. innocua*, *L. ivanovii*, *L. marthii*, *L. rocourtiae*, *L. seeligeri* (McLauchlin and Rees 2009), *L. weihenstephanensis* (Lang Halter et al. 2013), and *L. fleischmannii* (den Bakker et al. 2013). *L. monocytogenes* and *L. ivanovii* are pathogenic to warm-blooded animals and thus *L. monocytogenes* can causes disease in humans and animals. Evidence exists that links *L. ivanovii* to disease in humans, but disease is very rare (Elischerova et al. 1990; Cummins et al. 1994; Lessing et al. 1994; Snapir et al. 2006). *Listeria* spp. are commonly considered saprophytes (organisms that live on dead or decaying organic matter); they live in and can easily be isolated from soil as confirmed in a recent study (Strawn et al. 2013). *L. innocua* and *L. seeligeri* are commonly isolated *Listeria* species (Sauders et al. 2012). Because nonpathogenic *Listeria* spp. can be more common than *L. monocytogenes* in some environments, it has become a common practice in food manufacturing to test for *Listeria* spp. in the processing environment as a *L. monocytogenes* management tool. The premise of this testing strategy is that if any *Listeria* spp., notably nonpathogenic species which are presumed to be more prevalent, can be controlled or eliminated in the food handling environment (e.g., on food and non-food contact surfaces), the risk of the environment and subsequently food product being

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contaminated with *L. monocytogenes* is very low. Recent and ongoing studies by our group indicate, however, *L. monocytogenes* is more frequently recovered from food- and nonfood contact surfaces in retail delis compared to the nonpathogenic *Listeria* spp. (Simmons et al. unpublished).

5.1.2 L. monocytogenes *is a Human Foodborne Pathogen That Can Contaminate Ready-to-Eat Foods*

Listeria monocytogenes is a foodborne pathogen which causes relatively few illnesses annually in the United States and Canada, but it has one of the highest case fatality rates among foodborne pathogens, i.e., as many as 20–30 % of cases result in death (Rocourt et al. 2003). The Center for Disease Control and Prevention (CDC) estimates approximately 1,600 cases of listeriosis, 1,500 hospitalizations, and 260 deaths occur annually in the USA (Scallan et al. 2011). Health Canada estimates 178 cases per year in Canada (Thomas et al. 2013). Approximately 99 % of listeriosis cases result from contaminated food (Scallan et al. 2011). Ready-to-eat (RTE) deli meats, followed by dairy products, and frankfurters that have not been reheated are the highest risk food categories that may result in listeriosis in the USA (FDA/FSIS 2003). A 2003 survey conducted in the USA found that RTE meats handled in retail delis were six times more likely to be contaminated with *L. monocytogenes* than the equivalent product prepackaged and shelf-ready (Gombas et al. 2003). Recent studies have shown that *L. monocytogenes* can be prevalent and persistent in retail deli environments (Hoelzer et al. 2011b; Simmons et al. unpublished). Understanding how and where *L. monocytogenes* can live in the retail environment and implementing effective control strategies—sanitation procedures, management practices, and quality controls—are among the best strategies to help prevent illness and protect public health.

5.1.3 *Listeriosis Symptoms and Mechanism of Disease*

Listeriosis is caused by consuming food contaminated with live *L. monocytogenes* cells (Farber and Losos 1988). As an opportunistic pathogen, *L. monocytogenes* causes two forms of disease (Lecuit 2007). In healthy adults, the infection may result in febrile gastroenteritis. This is a mild, self-limiting disease and symptoms include fever, headache, vomiting, diarrhea, or arthralgia (joint pain). However, *L. monocytogenes* can cause an invasive infection in immunocompromised hosts. Immunodeficiency can result from many conditions including HIV infection, chemotherapy, pregnancy, intentional immunosuppression for organ transplant, and advanced age. *L. monocytogenes* attaches to and invades the epithelia cells of the small intestine, and can migrate to the mesenteric lymph nodes, and then to the liver and spleen via the blood stream (Farber and Losos 1988; Lecuit 2007). Victims

of invasive listeriosis may remain asymptomatic for days to months. Early symptoms can include mild flu-like fever, nausea, headaches, and body aches between 3 and 70 days after consumption of contaminated food. Disease progresses as the bacteria cross the blood–brain barrier, resulting in meningitis (inflammation of the membrane around spinal and brain tissues) and/or encephalitis (swelling of the brain). Symptoms may include confusion, seizures, or impaired motor function. Approximately 20–30 % of listeriosis cases result in death (Rocourt et al. 2003; Silk et al. 2012).

Globally, listeriosis will remain an important foodborne illness due to the fact that the vulnerable population is growing. Advances in medicine and nutrition help immunocompromised persons with advanced age, disease, or under medical treatment live longer. European Union member countries reported a 19 % increase in listeriosis cases from 2008 to 2009 (EFSA 2011). In the USA and Europe, there has been a significant increase in the number of listeriosis cases in adults >65 years of age (Little et al. 2010). Among listeriosis cases that occurred in the USA between 2004 and 2009, over 50 % of cases were in adults >65 years of age; this increased to 58 % of reported cases from 2009 to 2011. Specifically, there were 400 cases of listeriosis in adults >65 years and 234 of nonpregnancy associated cases in adults <65 years from 2004 to 2009. However, from 2009 to 2011, there were 950 cases and 474 nonpregnancy associated cases in adults >65 and <65 year of age, respectively (Silk et al. 2012, 2013).

Pregnant women are 8–18 times more likely to suffer an invasive infection than healthy, nonpregnant women (Southwick and Purich 1996; Silk et al. 2012). During the third trimester of gestation, the mother's immune system is naturally suppressed to prevent her body from rejecting the fetus. An infected mother may experience flu-like symptoms (e.g., fever, nausea, body aches), but the greatest danger is to the fetus since *L. monocytogenes* has a tropism for the placenta resulting in fetal infection (Smith 1999). High levels of *L. monocytogenes* in the placenta can result in spontaneous abortion or still birth; infected surviving neonates may suffer mental retardation (Farber and Losos 1988; Southwick and Purich 1996; Lecuit 2007). While the overall rate of listeriosis has not significantly increased or decreased in the USA since 2004, there was a significant increase in pregnancy-associated listeriosis in Hispanic women from 2004 to 2009 (Silk et al. 2012), and 43 % of pregnancy-associated listeriosis cases from 2009 to 2011 occurred in Hispanic women (Silk et al. 2013).

5.2 *L. monocytogenes* in Foods and Food Systems

5.2.1 L. monocytogenes *Prevalence in the Environment*

Raw ingredients and water are both potential sources of contamination (Lawrence and Gilmour 1995; Ojeniyi et al. 1996). Researchers have isolated *L. monocytogenes* from 20 to 35 % of ruminant farm environment samples and from >20 % of

cattle fecal samples (Nightingale et al. 2004, 2005). *L. monocytogenes* also can be isolated from a number of nonruminant species' feces such as poultry (Weber et al. 1995), wild birds (Fenlon 1985), swine (Hayashidani et al. 2002; Yokoyama et al. 2005), horses (Weber et al. 1995; Gudmundsdottir et al. 2004), farmed fish (Miettinen and Wirtanen 2005), and some domestic animals. *L. monocytogenes* in ruminants and on farms contributes directly to human disease (e.g., consumption of contaminated raw milk (Ryser 1999)) and indirectly by introduction into food processing plants or onto vegetables through contaminated manure (e.g., Fenlon et al. 1996; Rorvik et al. 2003). In a recent study on produce farms, *L. monocytogenes* was detected in 17.5 % of fields. Soil cultivation, irrigation, and presence of wildlife within a given number of days prior to sampling, all increased the likelihood of a soil sample testing positive for the presence of *L. monocytogenes* (Strawn et al. 2013).

5.2.2 *Cross-Contamination and Growth of* L. monocytogenes *in Food*

The common occurrence of *L. monocytogenes* in nature and agricultural systems contributes to the frequent introduction of the pathogen into foods. *L. monocytogenes* is a salt- and acid-tolerant organism and can grow at and below refrigeration temperatures with little oxygen (McLauchlin and Rees 2009). It is, however, sensitive to extreme acidity, pressure, and high temperature (McLauchlin and Rees 2009). Cooking kills *L. monocytogenes*, thus preventing disease. As *L. monocytogenes* can be killed by heat, contaminated raw ingredients rarely cause illness directly when food is heat treated. The more likely source of *L. monocytogenes* on foods is cross-contamination during processing after heating (e.g., slicing, casing removal, or packaging), which transfers the pathogen onto already cooked, RTE products (Lawrence and Gilmour 1995; Pradhan et al. 2011). Departments that handle raw meat products and RTE foods must pay particular attention to prevent cross-contamination. For example, 15–34 % of raw chicken sampled at retail was positive for *L. monocytogenes* (Cook et al. 2012). Poor food handling practices could result in products such as deli meat becoming inadvertently contaminated with *L. monocytogenes*. Cross-contamination alone does not create a risk of listeriosis. The infectious dose or dose response (the number of cells required to cause illness) varies and is not conclusive (McLauchlin et al. 2004). In general, it is thought to be high so the few cells transferred to foods during cross-contamination are not typically enough to cause illness (Vazquez-Boland et al. 2001). However, if the food product supports the growth of *L. monocytogenes*, the few transferred cells may multiply during storage (even at refrigeration temperature) to potentially infectious levels before consumption.

5.2.3 *Ready-to-Eat Foods Are Most Likely to Causes Listeriosis*

The majority of listeriosis cases (99 %) are linked to food (Scallan et al. 2011). Risk assessment models, epidemiological studies, and product testing have identified the greatest risk of listeriosis from delicatessen meats, contaminated cheeses, unpasteurized (raw) fluid milk, un-reheated frankfurters, smoked seafood, and cooked crustaceans (Rocourt and Cossart 1997; FDA/FSIS 2003; EFSA 2007; Lianou and Sofos 2007). These RTE products have the highest risk per serving for causing listeriosis due to three factors: (1) processing after cooking exposes the product to the environment and increases the risk of cross-contamination, (2) these foods support *L. monocytogenes* growth during refrigerated storage, and (3) consumption without cooking or re-heating allows any bacteria present on the food to be ingested and potentially cause disease. A risk assessment identified delicatessen meats as the highest risk per capita and per serving for causing listeriosis (FDA/FSIS 2003). Specifically, the U.S. Food and Drug Administration (FDA) and the U.S. Food Safety and Inspection Service (FSIS) estimated that about 90 % of human listeriosis cases in the USA are caused by the consumption of contaminated deli meats (FDA/FSIS 2003). From 1998 to 2011, there were 38 confirmed outbreaks of listeriosis (CDC 2013a). Of these outbreaks, 13 were associated with RTE meat products (e.g., deli meats, hotdogs). The most significant outbreak among these occurred in 1998, when 101 people became ill and 21 subsequently died from consumption of contaminated hotdogs and deli meats produced at a single plant (Mead et al. 2006). However, recent outbreaks in the USA have been linked with soft-ripened cheese (six cases) (CDC 2013b), aged ricotta salata cheese (22 cases) (CDC 2012a), and fresh cantaloupe (147 cases) (CDC 2012b). The 2011 cantaloupe-associated listeriosis outbreak caused 33 deaths and one miscarriage; this was the most deadly foodborne disease outbreak in the USA in 10 years. It is important to note that these products are typically considered RTE, although there are recommended handling guidelines for some products (e.g., washing cantaloupe).

5.3 *L. monocytogenes* in the Retail Deli Environment

5.3.1 *Risk Assessment Predicts That Most Deli Meat-Associated Cases of Listeriosis are from Deli Meats Sliced or Handled in Retail Delis*

A study in the USA in the early 2000s found that luncheon meats sliced at retail were found to be six times more likely to carry *L. monocytogenes* than prepackaged meats; deli salads three times more likely, and seafood salads five times more likely to be contaminated if handled at retail rather than manufacturer packaged (Gombas et al. 2003). Two independent risk assessments conducted in the USA concluded that approximately 83 % of listeriosis cases were caused by RTE meats

contaminated in retail delis (Endrikat et al. 2010; Pradhan et al. 2010). A recent USDA/FDA risk assessment concluded that implementing effective food safety practices in delis to control growth, cross-contamination, and potential sources of *L. monocytogenes* in addition to continued sanitation will prevent illness from foods handled at retail (USDA-FSIS and FDA 2013).

Retail delis have very different operating conditions and expectations than a typical RTE food production/manufacturing facility. *L. monocytogenes* may enter the deli on customers' and workers' shoes, cart wheels, raw meats, fresh produce, and RTE meats handled in the store. Studies conducted in the US in 2009–2011 found that 55–65 % of retail delicatessen establishments have *L. monocytogenes* on food contact and nonfood contact surfaces (Sauders et al. 2009; Hoelzer et al. 2011b; Simmons et al. unpublished). In some deli departments, contamination may be found on almost 40 % of all surfaces tested (Simmons et al. unpublished). Deli meats, salads, and cheeses may be sliced, repacked, or portioned for customers in retail stores. All of these processes expose the food to the environment, food handlers, and equipment, any of which may carry or transfer bacterial cells to the food if sanitation and hygiene procedures are not properly carried out.

5.3.2 *Nonfood Contact Surfaces Are More Likely to Be Contaminated*

The likelihood of *L. monocytogenes* contamination varies based on the type of surface (Table 5.1). Nonfood contact surfaces (NFCS) (e.g., floors, drains, walls) harbored *L. monocytogenes* on 15–20 % of samples, while only 2–4 % of food contact surfaces (FCS) (e.g., slicer blades, utensils, cutting boards, countertops) were contaminated (Sauders et al. 2009; Hoelzer et al. 2011b; Simmons et al. unpublished). NFCS are more likely to be contaminated due to (1) the foot traffic which may introduce and spread the bacteria; (2) many are soil collecting points from the entire environment (e.g. drains); and (3) infrequent cleaning may allow pathogen growth. Irrespective of the surface type, ineffective cleaning and sanitation can allow *L. monocytogenes* to grow and persist, potentially remaining for months or years in the deli environment (Simmons et al. unpublished).

5.3.3 *Transient v. Persistent* L. monocytogenes *Contamination: the Difference Between Short- and Long-Term Challenges*

In delis with *L. monocytogenes* contamination, distinguishing between transient and persistent contamination patterns determines which actions are needed to eliminate the organism. Transient organisms, those that can be introduced and

Table 5.1 *L. monocytogenes* prevalence across different sites in the retail deli (adapted from Hoelzer et al. 2011b)

Sample location	Percent positive samples (95 % CI)[a]		Total positives	Total samples tested
Food of food contact surfaces				
Product (food)	1.5	(0.6–3.1)	7	462
Slicer	2.7	(0.9–6.3)	5	183
Utensils (bowl, cutting board, others)	4.2	(2.2–7.0)	13	314
Bowl[b]	4.8	(0.6–16.2)	2	42
Cutting board[b]	7.1	(3.3–13.1)	9	127
Other utensils (e.g., knife, spoon, tongs)[b]	1.4	(0.2–4.9)	2	145
Multiple food contact areas (e.g., cutting board)	5.9	(0.7–19.7)	2	34
Deli case	6.9	(4.1–10.9)	17	246
Raw meat/seafood display	9.1	(0.2–41.3)	1	11
Subtotal	3.6	(2.6–4.8)	45	1,250
Non-food contact surfaces				
Sink	13.5	(9.5–18.3)	34	252
Dairy case	13.6	(9.5–18.6)	32	236
Floor/drains	27.4	(23.8–31.1)	163	596
Deli area drain/floor[c]	16.1	(10.5–23.2)	23	143
Raw meat preparation area drain/floor[c]	39.4	(31.7–47.7)	60	152
Seafood area drain/floor[c]	25	(13.2–40.3)	11	44
Produce area drain/floor[c]	24	(15.8–33.8)	23	96
Walk in cooler drain/floor[c,d]	34	(25.2–43.6)	37	109
Other drain/floor areas[c]	17	(8.1–29.8)	9	53
Floor in dry aisle	7.9	(4.8–12.2)	18	228
Floor adjacent to entrance	13.9	(8.3–21.4)	17[f]	122
Walk in cooler	20.6	(15.3–26.7)	43	209
Walk in cooler shelves	6.1	(2.3–12.9)	6	98
Walk in cooler door handle	0	(0.0–84. 2)	0	2
Walk in cooler drain (K1)/floor (K2[c])	34	(25.2–43.6)	37	109
Cart wheels	7. 6	(3.5–13.9)	9	119
Produce preparation area	10.5	(1.3–33.1)	2	19
Milk crates	34.3	(19.1–52.2)	12	35
Miscellaneous areas (e.g., shopping baskets, icemaker, etc.)	0	(0.00–15.4)	0	23
Subtotal	17	(15.2–18.8)	293	1,731

[a]Exact binominal confidence interval
[b]Individual subcategories that are part of "utensils"
[c]Individual subcategories that are part of "floor/drain"
[d]Results shown twice, as subcategory of "floor/drain" and of "walk-in cooler"

distributed by daily activity (e.g., shoes, carts, contaminated product), can be controlled or eliminated by routine sanitation. The key to effectively managing these organisms is through validated and verified sanitation programs. Managers and employees should aim to prevent recontamination by controlling potential sources (e.g., raw meat, traffic flow from contaminated areas, contaminated products). Persistent *L. monocytogenes* are much more difficult to eliminate and control. Persistent contamination is when the same *L. monocytogenes* strain remains in the environment for months or years by colonizing the deli environment in "niches." These niches can occur in equipment, close fitting metal to metal or metal to plastic parts, worn rubber door seals, cracked floors and walls (Miettinen et al. 2001; Tompkin 2002; Holah et al. 2004; Wulff et al. 2006; Ferreira et al. 2011), and about any surface that cannot be or is not routinely cleaned and sanitized. Persistent *L. monocytogenes* contamination of FCS and other environmental surfaces from which bacterial cells may be transferred to foods is among the most important and direct routes of contamination of RTE meat and poultry products (Lawrence and Gilmour 1995; Miettinen et al. 2001; USDA-FSIS 2003). *L. monocytogenes* can remain in the environment over time due to ineffective sanitation, which can result in biofilm formation. Biofilms are complex matrices of bacteria, carbohydrates, and proteins that allow the bacteria to survive, grow, and potentially be released into the environment over long periods of time. Tartar buildup on teeth is a common example of a biofilm. A biofilm is "stronger" than single bacteria cells and it can be resistant to destruction by soaps and sanitizers. A mature biofilm slowly releases living cells, which can spread throughout the environment, potentially forming biofilms on other surfaces or become a source of cross-contamination in foods. Removing biofilms requires significant mechanical force (e.g., scrubbing).

Studies by our group have shown that in many retail stores, the same strain is often found on both FCS and NFCS (Sauders et al. 2009; Hoelzer et al. 2011b; Simmons et al. unpublished). We use techniques such as Pulsed-Field Gel Electrophoresis (PFGE) and ribotyping to essentially DNA fingerprint *L. monocytogenes* isolates recovered from environmental samples. We have found *L. monocytogenes* isolates with the same DNA fingerprint on the slicer, deli case, sink, and utensils in the same store (Hoelzer et al. 2011b). In a very recent study by our group, PFGE showed that for 11 of 30 stores studied, one or more PFGE types were isolated at least three times. This is strong evidence for persistence of *L. monocytogenes* in these stores. In some stores, PFGE patterns for isolates from NFCS were distinct from patterns of isolates from FCS, suggesting limited cross-contamination between these sites in some stores. Persistent *L. monocytogenes* strains have been recovered in delis up to 1.5 years after first isolation (Hoelzer et al. 2011b) and in manufacturing facilities up to 12 years after initial isolation (Orsi et al. 2008). Persistent *L. monocytogenes* strains living in a biofilm in slicers in a RTE deli manufacturing facility was the cause of a 2008 Canadian listeriosis outbreak which resulted in 57 illnesses and 22 deaths (Weatherill et al. 2009).

5.3.4 L. monocytogenes *Is Transmitted by Hands, Gloves, Equipment, and Food Products*

Whether dealing with transient or persistent *L. monocytogenes*, transmission routes through the deli are control points to prevent cross-contamination. Bacterial transmission refers to how bacteria move through an environment—to and from food, FCS and NFCS including equipment, tools, and workers. As discussed earlier, cooking and other treatments kill *L. monocytogenes*, so foods are typically free of foodborne pathogens unless contaminated after thermal processing. Controlling the transfer of bacteria from contaminated surfaces and products to RTE foods prevents foodborne illness. The most comprehensive contamination and transmission pattern studies in retail delis to date were conducted in mock deli environments (Gibson et al. 2013; Maitland et al. 2013). Fluorescent compounds were used to mimic *L. monocytogenes* contamination on different surfaces, while volunteers performed a sequence of common deli tasks such as slicing, weighing, packaging, and serving ham to customers under different contamination source scenarios. By tracking the spread of fluorescence, researchers identified potential transmission routes based on the source of contamination. Other transmission studies used expert elicitation (Hoelzer et al. 2011a), direct observation of deli task sequencing (Lubran et al. 2010), and statistical modeling (Hoelzer et al. 2012) to characterize the movement of *L. monocytogenes* in this environment.

Worker hands and gloves are the most likely vehicle to transfer contamination to any deli surface (Hoelzer et al. 2011a; Gibson et al. 2013; Maitland et al. 2013). Clean gloves provide a sufficient barrier from contamination present on bare hands, but contaminated gloves may transfer contamination similar to bare hands (Maitland et al. 2013). In the USA, frequent hand washing and glove changes, particularly after contact with NFCS, which are most likely to harbor *L. monocytogenes* (Sauders et al. 2009; Simmons et al. unpublished; Hoelzer et al. 2011a), are needed to comply with the Food Code (FDA (2013)). Lubran et al. (2010) observed hand washing occurred at only 2–17 % of the recommended frequency in retail delis, highlighting a clear opportunity to improve compliance.

Slicers come into contact with the vast majority of RTE meat and cheese sold from a deli counter. The slicer may be a source of contamination in two ways: (1) transfer point for *L. monocytogenes* from contaminated products onto previously uncontaminated products (Gibson et al. 2013; Maitland et al. 2013), or (2) they may harbor an environmental niche for persistent *L. monocytogenes* growth (Weatherill et al. 2009). For example, if someone were to slice a contaminated meat chub, *L. monocytogenes* cells may remain on the slicer blade, carriage tray, and/or support trays (Gibson et al. 2013; Maitland et al. 2013). These bacteria could remain on the slicer until the next chub is sliced, slowly transferring onto the noncontaminated product. The first 10 slices served to a customer and the remaining unsliced chub returned to the service case may all contain *L. monocytogenes* due to product–product cross-contamination via the slicer (Gibson et al. 2013; Maitland et al. 2013).

The slicer harboring persistent *L. monocytogenes* is a more concerning scenario, as all products handled on the slider may become contaminated. Persistent contamination may indicate inadequate equipment maintenance, poor equipment design, or ineffective sanitation processes.

Transferring bacteria from floors and drain covers to FCS was not detected in a mock deli (Maitland et al. 2013). This study was limited to a group of volunteers without previous food service experience working in a controlled environment for a brief period of time. From practical experience, we are concerned about scenarios such as untied shoe laces dragging on the floor, dropped utensils, or customer-interrupted trash clean-up, which may require inadvertent employee contact with floors or drains creating opportunities for NFCS to FCS transmission not observed in the mock deli environment. In our most recent study, we found the same DNA fingerprint from *L. monocytogenes* isolated from the floor and from FCS (Simmons et al. unpublished). While these studies cannot determine the direction of transfer (e.g., from the drain to the sink or from the sink to the drain), it underscores that this pathogen can be transmitted throughout the deli environment and that control strategies are critical to prevent it from contaminating foods.

5.4 Control Strategies to Eliminate *L. monocytogenes* and Prevent Listeriosis

Preventing listeriosis from foods handled at retail is a complex process and difficult to measure. The first step is full cooperation and participation in food recalls. RTE foods are routinely tested by manufacturers and regulatory agencies, and those that are contaminated with *L. monocytogenes* are recalled to remove them from the market to ensure public safety. However, deli personnel must understand that RTE products processed (e.g. sliced, re-portioned, or packaged) at retail are at risk for cross-contamination in stores and manufacturing-based controls alone are not enough to prevent all listeriosis cases. The 2013 US Interagency Retail *L. monocytogenes* Risk Assessment Workgroup recommended five targets for reducing the risk of listeriosis from retail foods: (1) control growth through the use of growth inhibitors in products and temperature control during storage; (2) control cross-contamination during routine deli operations; (3) control contamination at its source: incoming products, the environment, or niches; (4) continue sanitation to eliminate *L. monocytogenes* from the environment; (5) identify key routes of contamination to RTE foods, such as the slicer (deli meats and cheeses) or serving utensils (deli salad) (USDA-FSIS and FDA 2013).

Business managers and merchandizers determine which products will be sold (RTE meats with or without growth inhibitors; pasteurized or unpasteurized cheeses), the number of labor hours allocated to sanitation, which chemicals are used, and many other factors which can impact upon the safety of retail products and prevalence and persistence of *L. monocytogenes*. However, immediate supervisors and managers drive the quality of food safety practices more than any other

factor (Neal et al. 2012). Managers who are committed to improving food safety in their stores can begin with the following five strategies.

1. *Temperature control of product in compliance with the Food Code*. The USA FDA Food Code contains the primary regulatory guidelines for ensuring food safety at retail. Key strategies to control *L. monocytogenes* growth include monitoring and maintaining deli service cases and walk-in cold storage rooms at temperatures below 41 °F (<5 °C) (FMI 2008, 2012; USDA-FSIS and FDA 2013). While *L. monocytogenes* can grow at refrigeration temperatures, reduced temperatures significantly reduce its growth rate. Maintaining product at refrigeration temperatures is among the most effective strategies to prevent *L. monocytogenes* from reaching high levels in foods and subsequently cases of foodborne listeriosis (USDA-FSIS and FDA 2013).
2. *Prevent cross-contamination*. Observational studies, (e.g., Lubran et al. 2010), underscore the need to increase the frequency of hand washing. Hand washing is a foundational component of a positive food safety culture. Aside from teaching employees why hand washing is important, managers can develop product handling strategies that minimize hand contact with NFCS and develop peer-to-peer accountability systems to encourage hand washing. It is also important to consider the flow of people and products near RTE foods (e.g., raw meat department, produce department). Because *L. monocytogenes* can be present in raw products (e.g., raw chicken), it is important to limit access to the deli to required departmental employees only (FMI 2008, 2012). Color coding equipment is a good practice to prevent cross-contamination between raw and RTE foods (e.g., cut raw poultry on yellow cutting boards, fresh produce on green). Similarly, for cleaning equipment, equipment intended for FCS should be labeled and reserved for only these surfaces (e.g., buckets, brushes). Separate equipment should be available for NFCS as these are more likely to harbor *L. monocytogenes*, e.g., 1 in 4 floor drains is contaminated with *L. monocytogenes* (Simmons et al. unpublished). Furthermore, the deli department should have its own cleaning equipment and should not provide or borrow equipment from other departments (e.g., brooms and hoses used in the raw meat department should not be shared with deli, dairy, bakery, or produce).
3. *Make the deli easier to clean and maintain*. Sanitation is a difficult, tedious, and time-consuming job. While it is difficult to change some aspects of the process, there are some obvious strategies to make it easier to do and more effective. It is important to remove "clutter" from the area. This can include unused and/or broken equipment, storage of chemicals below sinks, excess carts, old cleaning equipment, milk crates, etc. In short, personnel should be equipped with the tools and supplies needed to perform the job and the rest removed. Excess equipment and clutter have to be cleaned and cleaned around which significantly reduces (1) the likelihood that an area will be cleaned well or (2) cleaned at all. There should be designated space for cleaning equipment including hanging racks for brooms and shelves for sanitizers and detergents. An excellent example of an area that is typically challenging is under the single- and three-basin sink. This area is (1)

already difficult to clean, (2) often wet from dishwashing, and (3) a common storage area for chemicals and equipment. Results from our most recent study found that the floor wall juncture underneath the single-basin sink is one of the most common NFCS persistently contaminated with *L. monocytogenes*, i.e., >27 % of samples tested were positive for *L. monocytogenes* (Simmons et al. unpublished).

Our group is working to identify design challenges, practices, and other risk factors that increase the likelihood that a deli will harbor *L. monocytogenes*. While some effort has been made to enhance the hygienic design of delis and deli equipment, there is significant opportunity for improvement. Many challenges in the deli department that could result in niches require significant capital investments to remediate. For example, *L. monocytogenes* can routinely be found in pooled water on the floor, which results from improperly sloped floors. It is inarguably a good investment to fix the floor to enhance food safety and to reduce the risk of worker injury (e.g., due to slip hazard), however, the reality is that many delis have these challenges and they are not often a priority. If components of the deli environment or equipment are worn, damaged, or rusted, no amount of chemical or scrubbing will make it microbiologically clean. Well-repaired equipment, floors, and walls are easier to clean effectively, reducing the risk of harboring persistent *monocytogenes* in retail stores. In the interim, scheduled preventative maintenance of equipment and the deli is a viable strategy (FMI 2008, 2012). Preventive maintenance includes, but is certainly not limited to, replacing striated, nicked, or worn slicer blades; removing and replacing loose seals or caulking around sinks and walls; repairing damaged floor tiles; replacing worn or rusted components of cold rooms and deli cases; and making sure drains are free flowing.

4. *Verify cleaning was performed and performed correctly*. Sanitation remains one of the most important and obvious strategies to enhance food safety and to prevent disease. While it is difficult, time consuming, and hard work, creating a culture that champions the importance of sanitation is key. There is a big disparity between "saying" cleaning/sanitizing has occurred and "verifying" that it actually did. Cleaning and sanitation checklists, including employees' initials for accountability (FMI 2008, 2012), are good record-keeping strategies to track action. Visual inspection of surfaces after cleaning is also a good practice. Sanitizers are ineffective on surfaces that have visible soil or potential biofilms. Biofilms and some soils are difficult to visually see in many cases but there are cost effective, easy-to-use tools that can help identify challenges. Two common options are ATP (adenosine triphosphate; the "energy currency of all life") tests and protein test strips. These rapid tests detect general organic soils on a surface in 15–60 s, indicating if a surface is sufficiently clean to be sanitized. Our studies have identified a correlation between the ATP response value and the probability of detecting *L. monocytogenes* on a cleaned deli surface (Hammons et al. unpublished). ATP does not detect *L. monocytogenes*, but *L. monocytogenes* is more likely to be found in the presence of soils. While no one enjoys inspection and auditing processes, internal auditing programs can be a great way to identify opportuni-

ties for improvements that could enhance food safety. Our studies have found that engaging managers from nearby stores or other departments within the organization brings new perspectives which can help identify areas which need help or additional resources without the cost associated with third-party auditing services. Third-party audits, however, are an important way to verify food safety practices and to formally identify and address gaps.

5. *Provide leadership and support for food safety measures*. The leadership of the organization must create a culture that supports and values food safety. Food safety has to be championed within each service area by providing food safety training, education, and resources to all employees. Managers and other members of the leadership team must allocate sufficient labor hours to support effective cleaning during operating hours and after closing, and adjust sanitation schedules during busy periods. Budgeting for regular maintenance, chemicals, and tools needed to support sanitation should be routine and never viewed as crisis management (FMI 2008, 2012). Most importantly, lead by example. Supervisors and managers committed to excellence in food safety who follow and enforce health code compliance even when it is inconvenient, positively influence employees to do the same (Neal et al. 2012).

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