Transfer of *Listeria monocytogenes* during Mechanical Slicing of Turkey Breast, Bologna, and Salami

KEITH L. VORST,† Ewen C. D. Todd,‡ and ELLIOT T. RYSER¶

†Department of Food Science and Human Nutrition, 2108 South Anthony Hall and ‡The National Food Safety and Toxicology Center, Michigan State University, East Lansing, Michigan 48824, USA

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ABSTRACT

A commercial delicatessen slicer was used as the vector for sequential quantitative transfer of *Listeria monocytogenes* (i) from an inoculated slicer blade (~10⁸, 10⁵, or 10³ CFU per blade) to 30 slices of uninoculated delicatessen turkey, bologna, and salami, (ii) from inoculated product (~10⁸ CFU/cm²) to the slicer, and (iii) from inoculated product (10⁵, 10³, or 10³ CFU/cm²) to 30 slices of uninoculated product via the slicer blade. Cutting force and product composition also were assessed for their impact on *L. monocytogenes* transfer. Five product contact areas on the slicer, which were identified from residue of product bathed in Glow-Germ, were also sampled using a 1-ply composite tissue technique after inoculated product had been sliced. After being sliced with inoculated blades, each product slice was surface or pour plated on modified Oxford agar and/or enriched in University of Vermont medium. Greater transfer (P < 0.05) occurred from inoculated turkey (10⁵ CFU/cm²) to the five slicer contact areas from an application force of 4.5 kg as compared with 0 kg. On uninoculated product sliced with blades inoculated at 10⁸ CFU per blade, *L. monocytogenes* populations decreased logarithmically to 10⁵ CFU per slice after 30 slices. Findings for the inoculated slicer blade and product (10⁵ CFU per blade or cm²) were similar; *L. monocytogenes* concentrations were 10⁵ CFU per slice after 5 slices and enriched samples were generally negative for *L. monocytogenes* after 27 slices. For uninoculated product sliced with blades inoculated at 10³ CFU per blade, the first 5 slices typically produced *L. monocytogenes* at ~10 CFU per slice by direct plating, and enrichments were negative for *L. monocytogenes* after 15 slices. The higher fat and lower moisture content of salami compared with turkey and bologna resulted in a visible fat layer on the blade that likely prolonged *L. monocytogenes* transfer. As a result of cross-contamination, those delicatessen-sliced meats that allow growth of *L. monocytogenes* during prolonged refrigerated storage likely pose an increased public health risk for certain consumers.

*Listeria monocytogenes* has long been viewed as a serious postprocessing contaminant, and this pathogen can reside in some food-processing facilities for many years (6, 33). Endemic strains that persist in food manufacturing environments possess greater ability to adhere to food contact surfaces (23, 24, 28), with some strains attaching to stainless steel in as little as 20 min (24). In one study, Lunden et al. (22) demonstrated plant-to-plant transfer of *L. monocytogenes* via a dicing machine, with the same *Listeria* strain identified at three different facilities. Thus, processing equipment and other food contact surfaces can serve as vectors for the spread of *Listeria* during food manufacture.

Transfer of pathogens through slicing machines was recognized over 40 years ago. In one outbreak in Aberdeen, Scotland, that led to 469 cases of typhoid fever, slicing of contaminated corned beef at a delicatessen resulted in the transfer of *Salmonella* Typhi to other deli meats via the contaminated slicer over several days (14). In 1990, Humphrey (16) recovered *L. monocytogenes* from 10 of 32 retail delicatessen slicers surveyed in the United Kingdom. Three years later, Hudson and Mott (15) isolated *L. monocytogenes* from a delicatessen knife and slicing machines in Amsterdam supermarkets, and the pathogen also was found at most sites near a display case of processed meats.

*L. monocytogenes* is now a well-recognized contaminant of delicatessen products. Saunders et al. (30) identified this pathogen in smoked salmon, deli meats and cheeses, hot dogs, and seafood from 20 of 47 retail food establishments surveyed in New York state. In a large-scale survey by Gombas et al. (13), the prevalence of *L. monocytogenes* was approximately seven times greater in delicatessen-sliced (0.4%) than in manufacturer-sliced (2.7%) luncheon meats, and difficult-to-clean delicatessen slicers and other food contact surfaces presumably were responsible for the higher contamination rate. These findings and a report indicating that 75% of consumers purchase delicatessen-sliced rather than prepackaged luncheon meats (34) suggest substantial consumer exposure to *Listeria*.

Four major listeriosis outbreaks have been documented in the United States since May 2000, three of which were traced to consumption of delicatessen-sliced turkey breast (8, 9). These three outbreaks were responsible for a combined total of 91 listeriosis cases, including 11 deaths and six miscarriages, in 22 states and the recall of 44.3 million pounds of product. These outbreaks prompted the development of three alternatives mandated by the U.S. Depart-
ment of Agriculture (USDA) for controlling *Listeria* in delicatessen meats: (1) postpackage pasteurization, (ii) product reformulation to prevent *Listeria* growth, and/or (iii) increased product and environmental testing (37). These outbreaks also raised concerns regarding current food handling practices at the retail level as specified in the USDA Food Code (36). Based on a USDA Food Safety and Inspection Service risk assessment for *Listeria* in ready-to-eat meat and poultry products (34), 242 of the estimated 500 listeriosis fatalities each year are thought to be traceable to delicatessen meats. Thus, minimizing contamination at delicatessens will clearly have a major impact on reducing the incidence of listeriosis and in meeting the goals of the Healthy People 2010 program (35).

Because the number of *Listeria* cells transferred between commercial slicing machines and delicatessen meats was cited as both a major public health concern and a key data gap in several *Listeria* risk assessments (17, 32, 34), this study was designed to assess (i) the impact of application force on transfer of *L. monocytogenes* from contaminated ready-to-eat luncheon meats to a delicatessen slicer, (ii) the transfer of *L. monocytogenes* from an inoculated delicatessen slicer blade to un inoculated roast turkey, salami, and bologna, (iii) the transfer of *L. monocytogenes* from inoculated product to a delicatessen slicer and then to uninoculated product, and (iv) slicer blade wear after 1 and 2 years of use.

**MATERIALS AND METHODS**

*L. monocytogenes* strains. The following six strains of *L. monocytogenes* were obtained from Dr. Catherine W. Donnelly (University of Vermont, Burlington): CWD 205 (source unknown), CWD 578 (dairy plant), CWD 701 (Azore cheese), CWD 730 (dairy plant), CWD 845 (dairy plant), and CWD 1002 (pork sausage). These strains were chosen from a set of more than 190 strains based on their ability to form weak (CWD 205 and CWD 578), medium (CWD 701 and CWD 1002), or strong (CWD 730 and CWD 845) biofilms in a microtiter plate assay (18). All strains were maintained at ~80°C in Trypticase soy broth (TSB; Difco, Becton Dickinson, Sparks, Md.) containing 10% (vol/vol) glycerol. TSB containing 0.6% yeast extract (TSBYE; Difco, Becton Dickinson) was inoculated from the frozen stock cultures and incubated at 37°C for 24 h. After a second transfer in TSBYE, each culture was pelleted by centrifugation at 9,700 × g for 10 min at 4°C (Super T21, Sorvall Products, Newton, Conn.), resuspended in 9 ml of 0.1% peptone (Difco, Becton Dickinson), and combined in equal volumes to produce a six-strain cocktail containing approximately 10^8 CFU/ml. Cell concentration was determined by optical density at 600 nm and spiral plating (Autoplate 4000 spiral plater, Spiral Biotech, Inc., Norwood, Mass.) an appropriate dilution on modified Oxford (MOX) agar followed by 48 h of incubation at 35°C.

Delicatessen meats. One retail brand each of restructured roast turkey breast, Genoa hard salami, and bologna (2.5 to 3.0 kg each) was purchased in chub form from a local retailer (Gordon Food Service, Lansing, Mich.), held at 4°C, and used within 20 days. Product composition was reported on the package labels as follows: turkey breast—turkey breast, turkey breast, and <2% each for salt, dextrose, and sodium phosphates; salami—pork, beef, salt, and <2% each for dextrose, water, natural spices, sodium ascorbate, lactic acid starter culture, garlic powder, sodium nitrite, bishydroxyanisoile, bishydroxytoluene, and citric acid; and bologna—beef, pork, water, salt, and <2% each for dextrose, potassium lactate, sodium diacetate, sodium erythorbate, sodium nitrite, and oleoresin of paprika.

Fat, moisture, and crude protein were determined in triplicate for two lots of each product according to the Association of Official Analytical Chemists methods 991.36, 950.46, and 992.15, respectively (4).

**Delicatessen slicer.** A commercial gravity-fed delicatessen slicer (model 220F; Omcan Manufacturing, Niagara Falls, N.Y.) manufactured with an electropolished 304 stainless steel blade and other nonelectropolished components was used for slicing. To quantify numbers of *Listeria* cells recovered from the various slicer components, the slicer blade was milled from a diameter of 22 cm to 15.5 cm while maintaining the original surface profile, which had a beveled cutting edge 2.5 cm wide. The guard and back plate were scaled down to conform to the milled blade.

**Identification of delicatessen slicer product contact areas.** A chub of turkey breast was bathed in Glo-Germ powder (Glo- Germ, Moab, Utah) and immediately sliced (five slices) with the delicatessen slicer. The entire slicer was then viewed under UV light (260 nm) to identify the most likely areas to be contaminated. From this, the following product contact surfaces and areas were identified for later sampling: table (T), 160 cm²; back plate (BP), 192 cm²; guard (G), 161 cm²; blade (B), 181 cm²; and collection area (C), 176 cm² (Fig. 1).

**Surface profiling of delicatessen slicer blade.** Blade roughness values and overall surface profiles were obtained at the University of Illinois Center for Microanalysis of Materials (Urbana, Ill.) using a Sloan Dektak^3 ST stylus surface profilometer (Veeco Instruments, Inc., Woodbury, N.Y.). Surface profilometer measurements were taken along three radial 10-mm lines marked at approximately 120° intervals on the front and back sides of new and used blades after 1 and 2 years of use. Surface roughness data points were collected by recording the height of the stylus 40 times per s while traveling along a 10-mm line. Measurements were made along these lines with the stylus movement, ending approximately 0.5 mm from the blade edge. The data were then short-pass filtered (1 mm cutoff) to remove any effects from blade surface curvature commonly seen in delicatessen slicer blades.
Average roughness was calculated in micrometers according to the American National Standards Institute (1).

**Evaluation of slicer blade wear using scanning electron microscopy (SEM).** A field emission scanning electron microscope (CamScan 44FE, CamScan USA, Inc., Cranberry Township, Pa.) was used to visually assess new and used stainless steel slicer blades for pitting and oxidation. Three pieces (each 4 by 4 cm) were cut from new and 2-year-old slicer blades with a computerized numeric control laser cutter (ProAxis, Inc., West Lafayette, Ind.). Each slicer blade piece was cleaned with 95% ethanol, placed in the microscope chamber, and scanned from end to end.

**Impact of application force on L. monocytogenes transfer from turkey to a delicatessen slicer.** A replicated study (n = 3) involving inoculated roast turkey breast (approximately 10^5 CFU/cm^2) was conducted with the six-strain cocktail. Each turkey chub (22 cm in length by 8 cm in diameter) was surface inoculated with the six-strain cocktail (100 μl) lengthwise along a 1-cm-wide strip and held for 1 h at 4°C to allow the inoculum to absorb into the product. Application forces of 0 and 4.5 ± 0.9 kg were applied to the product against the back plate while slicing and were continuously monitored with a Chatillion force gauge (Amtek, Largo, Fla.) equipped with a product contact platform (10 by 10 cm). After each slice, the five previously identified contact areas were swabbed using the 1-ply composite tissue (CT) recovery method and each experiment was replicated three times for each of the three products. The turkey, salami, and bologna chubs were surface inoculated with the six-strain L. monocytogenes cocktail to obtain approximately 10^8 and 10^5 CFU/cm^2, as determined by spiral plating. After 1 h at 4°C to allow the inoculum to absorb, three to five slices were cut from each chub to artificially contaminate the blade; this same blade was then used immediately to obtain 30 slices of un inoculated product of the same or a different type.

When product containing 10^8 CFU/cm^2 was cut to contaminate the blade that was then used to cut uninoculated product, each of the first 20 slices of the uninoculated product were diluted 1:5 in PBS and spiral plated on MOX. The 10 remaining slices were diluted 1:5 in UVM and incubated for 48 h at 30°C, and the enrichment was streaked onto MOX. Mean Listeria populations were calculated at the limit of detection when enrichments were positive for Listeria. For products containing 10^5 CFU/cm^2, L. monocytogenes was recovered from each slice by homogenizing the slice in a 1:5 dilution of UVM and then pour plating duplicate 5-ml aliquots of homogenate in 25 ml of MOX in 150-mm-diameter petri plates.

**Quantification of injured Listeria cells on slicer blades.** Five pieces (4 by 4 cm) removed from the cutting edge of a new stainless steel slicer blade were inoculated by spreading 100 μl of the six-strain cocktail on the surface and then dried in a laminar flow cabinet for 1 h. The five slicer blade pieces were swabbed using the CT method, and 1 ml of PBS was added to each CT before use. The sample CT was mixed with 9 ml of PBS and homogenized in a stomacher for 1 min, and 50-μl aliquots of homogenate were spiral plated in duplicate on tryptose phosphate agar (Difco, Becton Dickinson) containing 0.5 g/liter ferric ammonium citrate and 1 g/liter esculin (mTPA) for recovery of healthy and injured cells and on mTPA containing 40 g/liter sodium chloride (mTPAN) and MOX for recovery of healthy cells as previously described (25). Bacteria on all plates were counted after 48 h at 35°C. The percentage of injured cells was determined by the following equation:

\[
\% \text{ injured cells} = \frac{\text{nonselective count} - \text{selective count}}{\text{nonselective count}} \times 100
\]

**Cleaning and decontaminating the slicer.** After use, the slicer was completely disassembled, and the slicer table, guard, and blade were wiped with a 1-ply CT and soaked for 30 min in a pan containing an activated 32% alkaline glutaraldehyde solution (CIDEX, Advanced Sterilization Products, Irvine, Calif.). Nonremovable components of the slicer (back plate and collection area) were disinfected with the same 32% alkaline glutaraldehyde solution.
solution and allowed to air dry for 30 min. A 1-ply CT soaked in 70% ethanol (vol/vol) then was used to clean all removable and nonremovable parts of the slicer, and all components were rinsed with deionized water and dried. Follow-up sampling with the CT method indicated that the slicer was free of Listeria. To prevent surface oxidation during storage, the slicer blade was coated with a thin layer of mineral oil, which was removed by flaming and with a KimWipe (Kimberly-Clark, Dallas, Tex.) immediately before use.

Statistical analysis. All Listeria transfer experiments were replicated three times. Impact of cutting force on transfer of Listeria to the five slicer contact areas and direct or sequential transfer from the inoculated slicer blade to uninoculated product and from inoculated product to uninoculated product via the slicer blade were analyzed using a general linear model and ANOVA for least significant differences in mean recovery (29). Mean differences in surface topography were analyzed with a general liner model at each time point (n = 3) (29).

RESULTS

Proximate analysis. Based on analyses of duplicate lots, roast turkey breast, bologna, and salami contained an average of 78, 60, and 43% moisture, <1, 27, and 36% fat, and 19, 10, and 17% protein, respectively.

Impact of application force on L. monocytogenes transfer from turkey to a delicatessen slicer. A force of 4.5 kg applied against the product while slicing yielded significantly greater Listeria transfer than a force of 0 kg when the total number of listeriae recovered from all five product contact areas was compared (P < 0.05). Fewer pathogen cells were transferred from the turkey to the table than to other slicer contact areas at 0 kg (P < 0.05) (Fig. 2), and transfer to the guard, collection area, and blade was not significantly different (P > 0.05) (Fig. 2). However, significantly more Listeria cells (P < 0.05) were recovered from the table and back plate when an application force of 4.5 kg was used than when a 0-kg force was used. No significant difference in numbers of pathogen cells transferred (P < 0.05) was found for the table, back plate, guard, blade, and collection area at a force of 4.5 kg, suggesting uniform contamination.

Transfer of L. monocytogenes from an inoculated delicatessen slicer blade to uninoculated product. Transfer of L. monocytogenes from an inoculated slicer blade containing 10⁶ CFU to uninoculated roast turkey and bologna was generally logarithmic (R² > 0.92) and was linear for salami (R² = 0.93), with no significant differences (P < 0.05) in average recovery between the three products (Fig. 3). Direct counts of all three products for each of the 30 slices revealed a 2-log reduction after the first 20 slices. Except for salami, similar results were obtained at an inoculation concentration of 10^5 CFU per blade (Fig. 4). Although a linear and logarithmic decrease in numbers of Listeria cells transferred was not found for salami, enrichment results were positive for Listeria out to 30 slices at an inoculation concentration of 10⁵ CFU per blade (Fig. 5 and Table 1).

At 10^5 CFU per blade, the sum total of Listeria cells transferred after 30 slices was significantly greater (P < 0.05) for salami than for turkey and bologna. Unlike turkey and bologna, a decrease in Listeria transfer was not evident during slicing of salami. Total Listeria populations transferred to turkey and bologna were not significantly different (P > 0.05) at an inoculation concentration of 10³ CFU per blade; however, significantly greater transfer again occurred with salami. At 10³ CFU per blade, enrichments for turkey and bologna were positive for Listeria in at least two of three replicates out to 19 and 23 slices, respectively, and

![FIGURE 2. Listeria monocytogenes populations recovered from a slicer used at an application force of 0 and 4.5 kg. Data are means ± standard deviations for three replicates.](image-url)

![FIGURE 3. Transfer of L. monocytogenes from an inoculated slicer blade (10⁶ CFU per blade) to uninoculated turkey, salami, and bologna. Data are means ± standard deviations for three replicates.](image-url)

![FIGURE 4. Transfer of L. monocytogenes from an inoculated slicer blade (10⁵ CFU per blade) to uninoculated turkey, salami, and bologna. Data are means ± standard deviations for three replicates.](image-url)
all 30 slices of salami were positive for *Listeria* by direct plating (Table 1). At 10^5 CFU per blade, enrichments were typically positive for *Listeria* out to 23 slices for turkey and salami and out to 20 slices for bologna.

**Sequential transfer of L. monocytogenes from inoculated product to a delicatessen slicer and then to uninoculated product.** At the higher inoculation concentration (10^8 CFU/cm^2), *L. monocytogenes* populations decreased approximately 2 log units after 15 slices (Fig. 6). However, numbers of *Listeria* cells transferred from surface-inoculated turkey containing 10^5 CFU/cm^2 to uninoculated turkey during slicing were not quantifiable by direct plating. Using product inoculated to contain 10^5 CFU/cm^2, *Listeria* was quantifiable when inoculated turkey was sliced before uninoculated salami, when inoculated salami was sliced before uninoculated turkey, and when inoculated salami was sliced before uninoculated salami (Fig. 7). After slicing inoculated turkey, the first 14 slices of uninoculated salami yielded *Listeria* by direct plating. After slicing inoculated salami, *Listeria* was also quantifiable in uninocu-

![FIGURE 5. Transfer of L. monocytogenes from an inoculated slicer blade (10^5 CFU per blade) to uninoculated turkey, salami, and bologna. Data are means ± standard deviations for three replicates.](image)

**TABLE 1.** Number of samples yielding *Listeria* by direct count and/or enrichment (n = 3) for delicatessen slicer (DS) to product (P) and P to DS to P transfer for turkey (T), bologna (B), and salami (S)a

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a No. of samples positive by direct plating/no. of samples positive by enrichment. NT, not tested.
lated turkey. Slicing of inoculated salami followed by slicing of uninoculated turkey yielded direct counts for the first 10 slices. A product inoculation concentration of $10^5$ CFU/cm$^2$ yielded positive *Listeria* enrichment results for at least two of three replicates out to 30, 8, and 15 slices when slicing of inoculated salami was followed by slicing of uninoculated salami or turkey or when slicing of inoculated turkey was followed by slicing of uninoculated salami, respectively (Table 1). At an inoculation concentration of $10^5$ CFU/cm$^2$, a comparison of means revealed significant differences ($P < 0.05$) in average recovery between slicing of inoculated turkeys followed by slicing of uninoculated salami compared with slicing of inoculated salami followed by slicing of uninoculated turkey and slicing of uninoculated salami followed by slicing of uninoculated salami, with a high degree of variability seen for all transfer scenarios.

**Slicer blade surface profiling.** A significant difference ($P < 0.001$) in surface topography was seen for both the front and back surfaces of the grade 304 stainless steel electropolished slicer blade over time. Initial average roughness values for the front and back sides increased from 0.653 and 0.752 $\mu$m to 0.935 and 0.836 $\mu$m after year 1 and to 3.251 and 5.045 $\mu$m after year 2. SEM micrographs revealed substantial wear and pitting on used as compared with new slicer blades (Fig. 8).

**Quantification of injured *Listeria* cells on slicer blades.** The nonselective medium (mTPA) afforded greater recovery of healthy and injured *Listeria* cells from stainless steel slicer blade pieces than did the selective media. With mTPAN and MOX, 61 and 73% of the *Listeria* cells were injured, respectively, after 1 h of drying in a laminar flow cabinet, which helps account for the recovery differences found when selective media were used for direct plating and enrichment.

**DISCUSSION**

The three products for slicing were chosen based on differences in fat and moisture content; turkey had the lowest fat (<1%) and highest moisture (78%), and salami had the highest fat (36%) and lowest moisture (43%). These variations in product composition resulted in visual differences in soiling of the slicer blade and other components after repeated slicing. The higher fat and lower moisture contents of salami resulted in a pronounced fat layer on the blade, which appeared to provide a favorable medium for *Listeria* dispersion and protection from the normal frictional forces during slicing. The higher moisture and lower fat content of turkey appeared to have a washing effect on the slicer blade, with fewer visible meat particles remaining on the blade after consecutive slices were produced. Lin et al. (20) also reported that a layer of fat developed on slicer blades and conveyor belts after slicing salami but not after slicing turkey.
slicing bologna or turkey. Salami does not support growth of *L. monocytogenes* and has not been implicated as a vehicle in listeriosis cases. However, the fat layer that develops on these blades after slicing salami likely provides novel means for prolonged *Listeria* transfer and cross-contamination of other *Listeria*-free products. The amount of mechanical energy applied to a stainless steel food contact surface during microbiological sampling also has a significant impact on bacterial recovery. Moore and Griffith (27) recovered more bacterial cells from stainless steel with increased mechanical energy. Our findings also suggest a direct relationship between mechanical energy, and application force and *Listeria* transfer.

Further differences in the numbers of *Listeria* cells transferred can be attributed to the fat and moisture content of these products. Lin et al. (20) found that the fat layer on the conveyor belt that collected during slicing of salami was associated with the highest numbers of *Listeria* cells on the blade, slicer housing, and conveyor belt. In additional work, these same authors also found increased *Listeria* transfer from contaminated slicer parts to turkey, salami, and bologna during slicing and subsequent growth of bacteria during prolonged refrigerated storage (21). Previous research has allowed identification of surfaces such as stainless steel, polyethylene, and polyvinyl chloride that are more conducive to bacterial transfer. Stainless steel reportedly is less likely to transfer bacteria than are polyvinyl chloride and polyethylene (3, 26). However, stainless steel is prone to scratching, pitting, and corrosion from use of chlorine- and acid-based sanitizers, making cross-contamination more likely (7, 31). On slicer blades, pits provide preferential sites for bacterial attachment and biofilm formation (10), which impact the bacterial transfer rate during slicing (19). In another study, product contact areas of a table-top bowl chopper that were most heavily contaminated with *Escherichia coli* O157:H7 during processing of inoculated beef were the top of the comb–knife guard and the knife (12). Cleanability of stainless steel is a problem also in the dairy industry. In similar studies, hairline cracks were found in six of nine stainless steel milk holding tanks and all 13 cheese vats in one dairy processing facility (5), suggesting the presence of environmental niches for bacterial pathogens.

When SEM and atomic force microscopy were used to assess stainless steel surfaces of different finishes, Arnold and Bailey (2) found that fewer bacterial cells attached to electropolished stainless steel (10^2 cells per SEM area) than to 2B finished, sandblasted, sanded, and electropolished stainless steel (10^3 cells per SEM area). In addition, no bacterial cell clumps were observed on electropolished surfaces, whereas more than 12 clumps were seen on all other surfaces.

In our study, significant changes in slicer blade surface topography were observed during 2 years of continuous use, and repeated, mildly abrasive cleaning and sanitizing produced pits or areas of high oxidation from the disintegration of the electropolished finish. These surface changes likely impacted *Listeria* transfer, with rougher blades allowing increased attachment of bacteria. Electron micrographs of new and used slicer blades (Fig. 8) reveal differences in the surface finish that result from repeated use and cleaning. Numerous pits and scores on worn slicer blades can serve as sites for bacterial attachment and thus lead to more extended bacterial transfer during slicing.

Transfer of *L. monocytogenes* at the lowest concentration of inoculum (10^3 CFU per blade) was difficult to quantify because a tailing effect was observed followed by sporadic recovery after five slices for all three products. Enrichment data provided some insight on the likelihood of transfer after extended slicing (>10 slices). Differences between initial concentration and total number of *Listeria* cells recovered for all concentrations of inoculum can be accounted for in part by injury. *Listeria* cells not accounted for by direct plating and injury results were likely transferred to other unsampled surfaces of the delicatessen slicer (Fig. 2) or lost as aerosols.

Based on guidelines established in the 2001 Food Code (26), equipment that is used for food preparation and has food contact surfaces must be cleaned every 24 h if held at <5°C or every 10 h when held at 10 to 12.8°C; cleanliness is defined as “clean to sight and touch.” These guidelines clearly allow ample time for bacterial attachment, growth, and subsequent transfer to previously uncontaminated products between cleanings. Food preparation appliances such as mechanical slicers have numerous components, such as the slicer blade and guard, that are difficult to clean and on which contamination is not always visually apparent. Findings presented in this study suggest ample opportunity for transfer of *Listeria* in delicatessens via mechanical slicers, with the highest risk of consumer exposure coming from the first 10 slices produced on a contaminated slicer. Thereafter, sporadic transfer was seen out to 28 to 30 slices for all inoculation concentrations and transfer scenarios (inoculated slicer to uninoculated product and inoculated product to uninoculated product via the slicer). In one recent study (11), delicatessen-sliced luncheon meats were more frequently contaminated with *L. monocytogenes* when the slices were produced in succession, thus suggesting repeated cross-contamination from the delicatessen slicer. Given that an estimated 75% of all luncheon meats sold are being sliced at delicatessens, ample opportunity exists for the contamination of delicatessen-sliced meats. Depending on product formulation, certain delicatessen meats that permit growth of *Listeria* may pose a public health risk to consumers when stored in home refrigerators for long periods of time.

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