Journal of Food Protection 88 (2025) 100599

Contents lists available at ScienceDirect

Journal of Food Protection

journal homepage: www.elsevier.com/locate/jfp

Recovery of *Salmonella* and *Listeria monocytogenes* from Nonporous Surfaces Based on Surface Sampler Type

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ARTICLE INFO

Keywords:
Food-contact surface
Nonwoven fabric sampler
Pathogen
Polypropylene
Sponge sampler
Stainless steel

ABSTRACT

Surface sampling devices ranging in material composition and size can be used in environmental monitoring programs. This study aimed to compare the bacterial recovery efficiency of surface samplers on stainless steel (SS) and polypropylene (PP) surfaces. Separate cocktails of *Listeria monocytogenes* and *Salmonella enterica* strains were spot inoculated (1 mL; 40 spots × 25 μL) on SS and PP surfaces at high (7 log) and low (4 log) concentrations. A cellulose sponge sampler, polyurethane foam sponge sampler, and polyolefin nonwoven fabric sampler were utilized for bacteria recovery from SS and PP surfaces at two surface areas: 1× [929 cm^2 (144 in^2)] and 2× [1858 cm^2 (288 in^2)]. The effect of prewet volume (5 mL, 10 mL) on bacteria recovery from PP and SS was also investigated with the nonwoven fabric sampler at high inoculum level and 1× surface area. Three experimental trials were conducted totaling 336 samples, and recovery percentages were based on the CFU recovered divided by the initial CFU added to each surface. Statistical analysis was performed to determine whether sampler type, pathogen type, inoculum concentration, surface type, and surface area were significant predictors of recovery percentage. A significant five-way interaction ($P = 0.0015$) was observed between the predictor variables; therefore, no conclusions can be made regarding the main effects. The recovery percentage of *L. monocytogenes* was significantly higher than *Salmonella* from PP surfaces across all three sampler types. For the nonwoven fabric sampler, the 5 mL prewet volume yielded significantly higher recovery ($P \leq 0.05$) for both bacteria combined at 10.66% (95% CI: 9.93, 11.44) compared to 3.09% (95% CI: 2.71, 3.52) recovery with the 10 mL prewet volume. However, the effect of volume on recovery depended on the interaction between surface type and inoculum level.

Several types of food contact surfaces are utilized in food handling and processing environments depending on the purpose of use, process conditions, cost of material, ease of cleaning, physical and chemical properties of material, and regulatory requirements. Major foodborne pathogens including *Salmonella* and *Listeria monocytogenes* can be a source of cross-contamination on food contact surfaces (Lahou & Uyttendaele, 2014). Persistence of pathogens on surfaces in direct contact with food can vary from hours to days, increasing the possibility of product contamination (Losito et al., 2017). Microbiological factors including population, growth phase, and strains of pathogen (Djebbi-Simmons et al., 2019; Martinon et al., 2012), environmental factors such as moisture and temperature (Bashir et al., 2022; Redfern & Verran, 2017; Margas et al., 2014), production material (Xie et al., 2024), food residue (Hamilton & Gibson, 2025; Jones et al., 2024; Lim et al., 2019), and attachment and biofilm formation capability (Di Ciccio et al., 2015; Dourou et al., 2011) contribute to the survival of bacterial pathogens on food contact surfaces in food processing facilities. Food contact surfaces always have a potential risk for pathogen transfer to foods when recommended or required hygiene and sanitation practices are not followed or do not appropriately manage the hazard.

Swabbing food contact surfaces is frequently used for microbiological evaluation of food processing environments, public kitchens, food preparation, and serving areas. Various surface samplers for different food environments are available in the market under a variety of brand names. The recovery efficacy of commercially available swabs may depend on several factors including surface characteristics, microbial adherence to surfaces, food contact surface materials, and the pressure applied to surfaces during sampling (Ismaïl et al., 2013; Jansson et al., 2020; Keeratipibul et al., 2017; Lahou & Uyttendaele, 2014; Lee & Pascall, 2017; Moore & Griffith, 2002). Sterile single-use samplers with different sizes and shapes are preferred by food producers and

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https://doi.org/10.1016/j.jfp.2025.100599
Received 17 March 2025; Accepted 8 August 2025
Available online 12 August 2025

auditors for food contact surfaces depending on the surface type and size of intended sampling area.

In the food environment, stainless steel surfaces and cutting boards made of petroleum-based plastics such as polyethylene (PE), polypropylene (PP), and polytetrafluoroethylene (PTFE) are commonly used due to ease of cleaning, durability, hygienic concerns, and recommendations by authorities. These surfaces are regularly swabbed to monitor hygienic conditions in food processing environments, public kitchens, and food preparation and serving areas (Losito et al., 2017; Ríos-Castillo et al., 2021; Sibanyoni & Tabit, 2019; Yassoralipour et al., 2023). In this study, the recovery performances of three surface samplers made of cellulose, polyurethane foam, and polyolefin nonwoven fabric were compared based on surface sampling of *Salmonella* and *Listeria monocytogenes* from two nonporous surfaces (stainless steel and PP cutting mats).

Materials and methods

Strains and inoculum preparation. Four serotypes of *Listeria monocytogenes* and *Salmonella enterica* were used. Bacterial serotypes, strains, and origins of utilized strains are listed in Table 1. Frozen cultures stored at −80 °C were cultured by streaking on tryptic soy agar (TSA; Becton Dickinson, Sparks, MD; Fisher Scientific, Fair Lawn, NJ) for *Salmonella* and brain heart infusion (BHI) agar (Hardy Diagnostics CRITERION, Santa Maria, CA) for *L. monocytogenes* strains. After incubation at 36 ± 1 °C for 24 ± 1 h, one colony of each *Salmonella* and *L. monocytogenes* strain was inoculated into 10 mL of tryptic soy broth (TSB; Becton Dickinson, Sparks, MD; Fisher Scientific, Fair Lawn, NJ) and BHI broth (Hardy Diagnostics CRITERION, Santa Maria, CA), respectively. All prepared cultures were incubated at 36 ± 1 °C for 20 ± 1 h. Cultures were transferred into 15 mL sterile centrifuge tubes containing 10 mL of TSB and BHI broth for another round of incubation at 36 ± 1 °C for 20 ± 1 h. After incubation, all culture tubes were centrifuged at 18,000 rpm for 10 min (Allegra X-30R, Beckman Coulter, Brea, CA) and the supernatants were discarded. Cells were resuspended in sterile 10 mL of 1 × phosphate-buffered saline (PBS) and centrifuged followed by removal of supernatant. The washing procedure was performed twice with sterile PBS. After the washing step, the pellets of strains were suspended in 5 mL of PBS to achieve an initial concentration of ~10^9 CFU/mL (Table 1). Inoculation levels were prepared by serial dilution at high and low concentrations of ~10^7 and ~10^4 CFU/mL, respectively.

Surfaces and surface samplers. Commercially available stainless steel (SS) 304 (Rose Metal Products, Inc., Springfield, MO) and PP cutting mat (TableCraft Products Company, Gurnee, IL) surfaces with an area of 929 cm^2 (144 in^2) and 1858 cm^2 (288 in^2) were used and are hereafter referred to as 1× and 2×, respectively. Surface samplers included cellulose (CELL) sponge sampler (Neogen™ Sponge-Sticks: 3.8 × 7.6 cm; Cat. No: SSL100; Neogen, Lansing, MI), polyurethane foam (PUF) sponge sampler (EZ Reach™ PUF: 3.8 × 7.6 cm; Cat. No.: EZ-DRY-PUR; World Bioproducts, Woodinville, WA), and polyolefin nonwoven fabric sampler (MM; MicroTally® MicroMitt™ sampler [12 cm × 12 cm], 80 GSM [grams per square meter]; FREMONTA, San Jose, CA).

Inoculation of surfaces. Sterile surfaces were spot inoculated with 1 mL (40 × 25 μL) of the prepared bacterial cocktails at either high (~10^7) or low (~10^4) concentrations. All surfaces were kept in a class II Biosafety Cabinet for 1 h with no air flow. Manufacturer's instructions with some modifications were followed for the use of samplers. Briefly, samplers were saturated with 5 mL (only for nonwoven samplers) or 10 mL of sterile PBS. Excess PBS was squeezed out of each sampler into the sample bag prior to surface sampling. Microbial recovery was performed as shown in Figure 1 with the tested surface samplers flipped over to the 'unused' side (backside of fabric sampler on fingers used for application) between vertical and horizontal sampling. The surface sampler was placed back in the sample bag with the excess buffer.

Microbiological enumeration. After sampling, 40 or 45 mL of PBS depending on the volume (5 or 10 mL) added to the sample bags for premoistening (for a total of 50 mL) was added to the sampler bags followed by stomaching for 1 min at 260 rpm. To quantify *Salmonella* and *L. monocytogenes*, serially diluted samples were spread plated onto xylose lysine Tergitol 4 agar (XLT-4; Hardy Diagnostics CRITERION, Santa Maria, CA) and CHROMagar™ *Listeria* (Kanto Chemical Co., Inc., Tokyo, Japan) plates, respectively. All surface-condition combinations were inoculated in duplicate for a given experiment, and samples and dilutions were analyzed in duplicate for quantification. Experiments were completed three times ($n = 3$). In total, *Salmonella* and *L. monocytogenes* were recovered with cellulose sponge, polyurethane foam sponge, nonwoven fabric (premoistened with regular [10 mL] and half reduced [5 mL] PBS by volume) surface samplers from stainless steel (SS), and polypropylene (PP) cutting mat surfaces with 1×

Table 1
Listeria monocytogenes and *Salmonella* serotypes, strains, origins, and initial concentrations before inoculum preparation utilized in this study

Pathogen	Strain (serotype)[a]	Outbreak/ Origin	Initial concentration (log CFU/mL)
L. monocytogenes	N3-031 (1/2a)	Hot Dog	9.26 ± 0.11
L. monocytogenes	R2-502 (1/2b)	Chocolate Milk	9.41 ± 0.08
L. monocytogenes	J1-094 (1/2c)	Human Sporadic	9.53 ± 0.04
L. monocytogenes	R9-5506 (4b)	Packaged Salad	9.41 ± 0.03
Salmonella Agona	447967	Oats Cereal	9.22 ± 0.13
Salmonella Enteriditis	R9-5272	Almonds	9.34 ± 0.14
Salmonella Newport	R9-5252	Tomatoes	9.26 ± 0.15
Salmonella Typhimurium	R9-5409	Peanut Butter	9.28 ± 0.06

[a] All strains except *Salmonella* Agona were obtained from the Institute for the Advancement of Food and Nutrition Sciences (IAFNS) culture collection at Cornell University, Ithaca, NY. *Salmonella* Agona was received from the U.S. FDA National Center for Toxicological Research, Jefferson, AR.

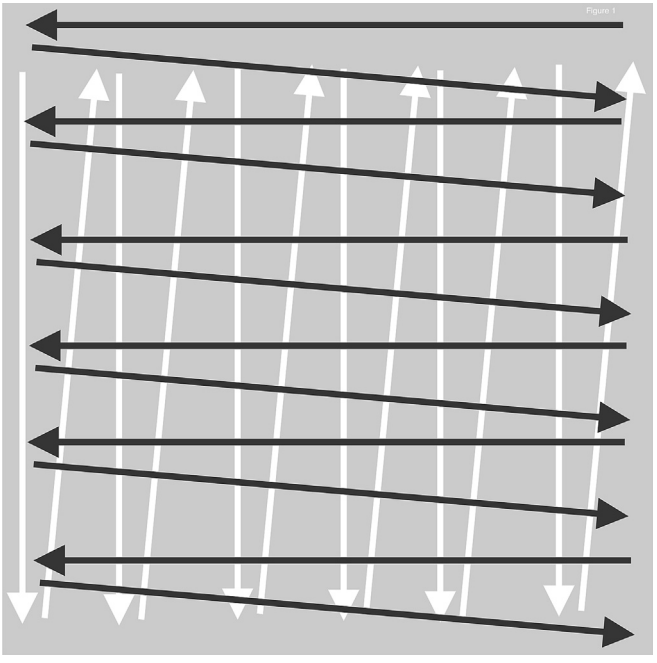

Figure 1. Sampling method for microbial recovery from surfaces. Created in Biorender.com.

and 2× surface after spot inoculation at low and high concentrations. In total, 336 samples were collected.

Statistical analysis. Three experimental trials were conducted to evaluate differences in recovery percentages of each bacterium observed between sampler types for all combination of factors (inoculum concentration, surface type, surface area) for a total of 288 samples in this initial analysis. Ninety-six samples (48 samples from the previous analysis plus 48 additional samples for a 5 mL prewet volume) were included in the subsequent analysis of prewet volume for the nonwoven fabric samplers. Recovery percentages were calculated by dividing the CFU recovered from each surface by the total amount of CFU initially added to each surface. Statistical analysis was performed to determine whether sampler type, pathogen type, inoculum concentration, surface type, and surface area were significant predictors of recovery percentage. Initial analysis of the data using a linear model indicated that the assumptions of normality and homoscedasticity were not met. Therefore, a generalized linear model (GLM) with binomial errors was used. However, the residual deviance was greater than the residual degrees of freedom; therefore, a GLM with quasibinomial errors was used to account for overdispersion. The log link function was applied to model the relationship between recovery percentage and predictor variables. Estimated marginal means were used to calculate treatment means and their 95% confidence intervals. Multiple pairwise comparisons were performed to identify statistical differences at $P \leq 0.05$. To determine the effect of prewet volume of the nonwoven fabric sampler, a GLM with quasibinomial errors was similarly constructed to test the effect of the independent variables (microorganism, volume, surface type, and inoculum level) on the response variable (recovery percentage). The relationship between recovery percentage and predictor variables was modeled using a log link function. A statistically significant difference was determined when $P \leq 0.05$. All data were analyzed in R (R Core Team, 2024) using *base, ggplot2* (Wickham, 2016), *ggpubr* (Kassambara, 2020), *emmeans* (Length et al., 2021), and *multcomp* (Hothorn et al., 2008) packages.

Results

Effect of sampler types on microbial recovery. The estimated recovery percentages after statistical analysis are plotted in Figure 2 to show the effect of three sampler types (CELL, MM, PUF) on recovery of bacteria (*Salmonella* and *L. monocytogenes*) at two inoculum concentrations (low [10^4] and high [10^7]) from two surface types (PP and SS) at two surface areas (1× and 2×). A significant five-way interaction ($P = 0.0015$) was observed between the predictor variables; therefore, no conclusions can be made regarding the main effects. The highest recovery percentage observed for *L. monocytogenes* was 10.2% (95% CI: 9.27, 11.26) using the PUF sampler from 2× area PP surface at a low inoculum level. For *Salmonella,* the highest recovery percentage was 4.56% (95% CI: 3.92, 5.30) again using the PUF sampler from 1× area PP surface at low inoculum volume. The PUF sampler consistently yielded slightly higher recovery percentages from PP surface for both bacteria compared to the other sampler types under all tested conditions. However, these differences were not statistically significant. For SS surface, no consistent differences in recovery were observed between the three sampler types for either bacterium.

The recovery percentage of *L. monocytogenes* was significantly higher than that of *Salmonella* from PP surfaces across all three sampler types. For SS surfaces, *L. monocytogenes* exhibited a similar trend, except under one condition (1× surface area, high inoculum concentration, and CELL sampler), but significant differences were not observed in most cases. For *Salmonella* on PP surfaces, recovery at both high and low inoculum levels was consistently lower from the 2× surface area compared to the 1× surface area across all three samplers, though the differences were not statistically significant (Fig. 2). No such trend was observed with SS surfaces for either bacterium.

Effect of prewet volume on bacterial recovery using the nonwoven fabric sampler. When using the 10 mL prewet volume with the nonwoven fabric sampler, excess liquid was observed on the surfaces after sampling, possibly impacting the recovery percentage of bacteria. To determine the potential impact, 5 mL and 10 mL prewet volumes were compared, and the estimated recovery percentage after statistical analysis is plotted in Figure 3. There was a significant three-way interaction between surface type vs volume vs inoculum level, and surface type vs inoculum level vs microorganism. These results emphasize that recovery depended on specific combinations of surface type, inoculum level, and volume or microorganism and not merely on the main effects, even though all four independent variables showed significant effects. Nonsignificant four-way and three-way interaction terms were removed from the full model to make it parsimonious.

The 5 mL prewet volume yielded significantly higher recovery ($P \leq 0.05$) for both bacteria combined at 10.66% (95% CI: 9.93, 11.44) compared to 3.09% (95% CI: 2.71, 3.52) recovery with the 10 mL prewet volume. However, the effect of volume on recovery depended on the interaction between surface type and inoculum level. For example, for a 5 mL prewet volume, a significant difference ($P \leq 0.05$) was observed between PP and SS surfaces with recovery of 13.86% (95% CI: 12.27, 15.61) and 5.07% (95% CI: 4.15, 6.17), respectively, at a high inoculum level. Meanwhile, for a 10 mL prewet volume, there was no significant difference between PP, 2.79% (95% CI: 2.14, 3.63), and SS, 1.99% (95% CI: 1.45, 2.73), at high inoculum level. Moreover, the other combinations of volume and inoculum level showed no significant differences ($P > 0.05$) between the PP and SS surfaces.

Similar to the results for comparing all sampler types at 10 mL prewet volume ("Effect of sampler types on microbial recovery"), a significantly higher recovery was observed for *L. monocytogenes* at 7.64% (95% CI: 6.94, 8.39), while a lower recovery was observed for *Salmonella* at 4.4% (95% CI: 3.92, 4.95) with the nonwoven fabric sampler for all factors combined. This observation was consistent across the various combinations of surface type and inoculum level. However, a significant three-way interaction was observed among these factors (microorganisms: surface type: inoculum level), suggesting that the mean recovery of the bacteria depended on the combined levels of surface type and inoculum level. This significant interaction may be due to the relatively higher percent recovery observed for *L. monocytogenes* at low inoculum level and 5 mL volume as compared to the other factor level combinations (Fig. 3). For surfaces, across all other factors, higher recovery was observed on average for PP [6.81% (95% CI: 6.17, 7.51)] compared to SS [4.95% (95% CI: 4.42, 5.54)]; however, this was dependent on the inoculum concentration and prewet volume used as well as the inoculum concentration and microorganism type.

Discussion

The present study investigated the impact of surface type, surface area, inoculum concentration, and surface sampler type on the recovery of *Salmonella* and *L. monocytogenes* from contaminated surfaces. The experimental findings suggest overall better recovery of *L. monocytogenes* from common food-contact surfaces when compared to *Salmonella*. However, the specific recovery percentage varied based on the specific combination of factors (Figs. 2 and 3). Keeratipibul et al. (2017) observed a greater recovery of gram-positive bacteria compared to gram-negative bacteria regardless of surface sampler type. For instance, there was an 8.2% difference in recovery of *L. monocytogenes* and *Salmonella* using a polyurethane foam sampler. The impact of bacterial gram-type on recovery from a variety of surfaces with a PUF sampler was also reported by Jones and Gibson (2022). The study authors observed an overall 1.5 log greater recovery of *L. monocytogenes* when compared to *Salmonella* Typhimurium across all factors (i.e., environmental conditions and surface type). These studies substantiate

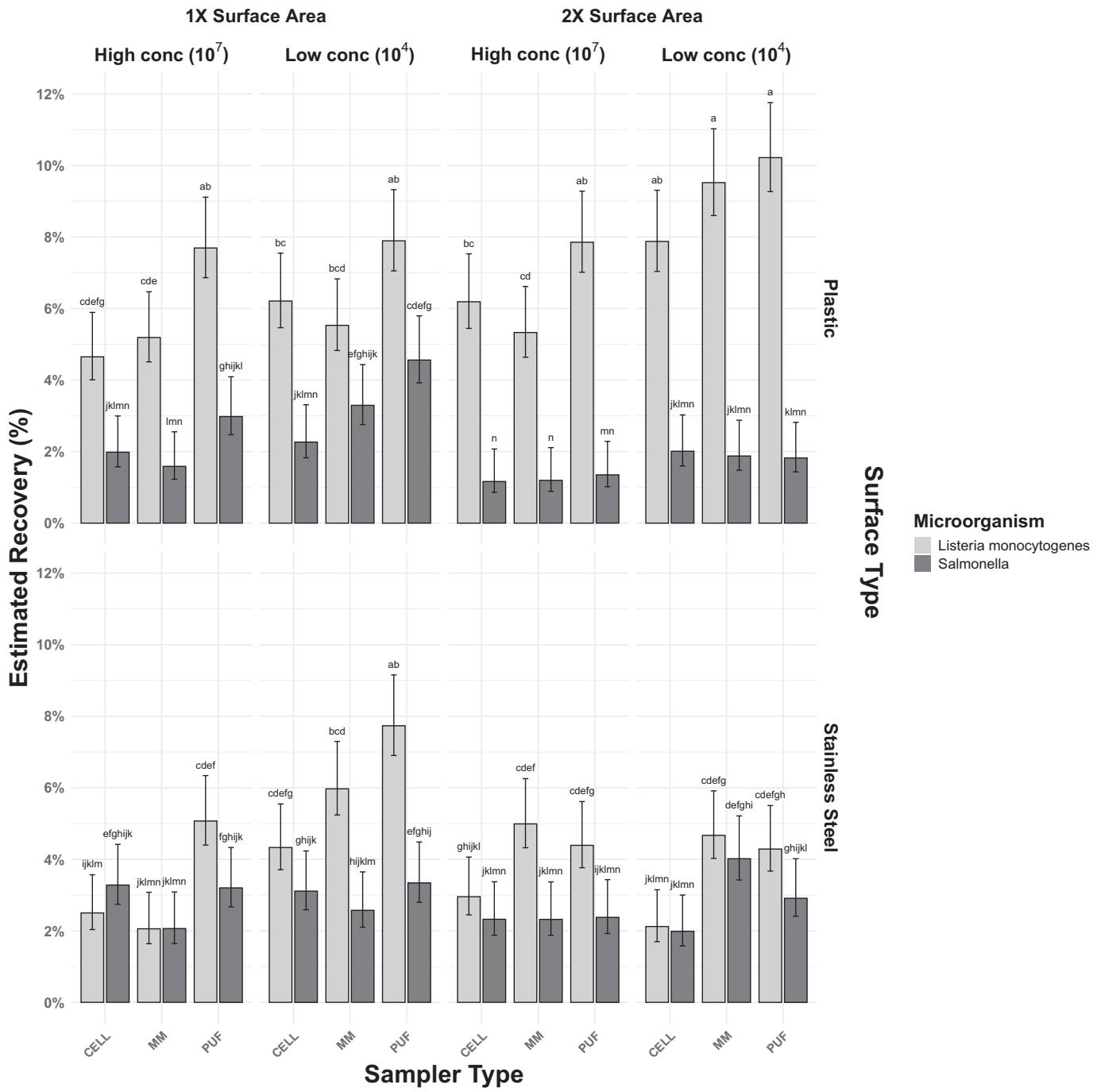

Figure 2. Estimated recovery (%) obtained from the generalized linear model with quasibinomial errors for *Listeria monocytogenes* and *Salmonella* using various sampler types and surface types (n = 288). Data are presented for two surface areas and two initial bacteria concentrations. Statistical differences between different treatments are denoted by compact letters over error bars at $P \leq 0.05$.

the trends in recovery percentage by bacterial gram-type reported in the present study.

Lahou and Uyttendaele (2014) observed that surface type (SS, high-density polyethylene, rubber) did not impact the recovery (presence/absence) of *L. monocytogenes* immediately after inoculation using a cellulose sponge sampler (3M™ Sponge-Stick), COPAN foam spatula, and PUF-based environmental swab (3M™ Enviro-Swab). However, when inocula were allowed to air-dry for one hour (i.e., like the present study), *L. monocytogenes* was not detected in 3.7–11.1% of samples from SS surfaces (Lahou & Uyttendaele, 2014). A previous study reported a similar trend for *Salmonella* recovery from PP and SS surfaces where recovery with a PUF sampler was significantly lower from SS surfaces; however, this difference was not observed for recovery *L. monocytogenes* from PP and SS surfaces (Jones & Gibson, 2022). Weir et al. (2016) also demonstrated greater average recovery percentage (calculated using $\log_{10}$-transformed data) of *Staphylococcus aureus* from plastic surfaces (80 ± 15%) when compared to SS surfaces (69 ± 19%). These previous studies are reflective of the generally lower recovery percentage of bacteria from SS surfaces observed in the present study regardless of sampler type and bacteria type (Fig. 2). The different recovery performance of surface samplers on SS and PP surfaces can potentially be explained by persistence and

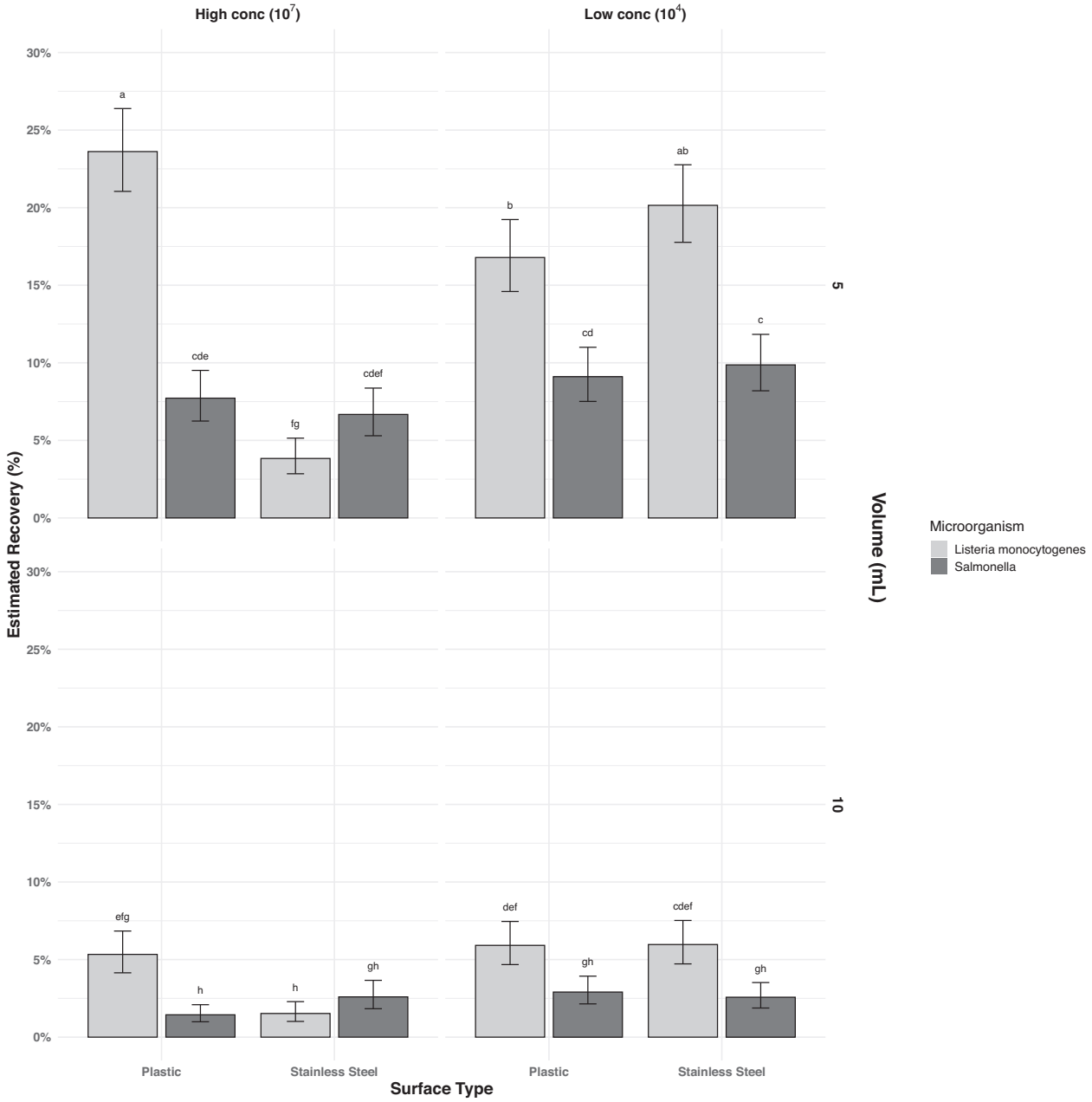

Figure 3. Estimated recovery (%) obtained from the generalized linear model with quasibinomial errors for *Listeria monocytogenes* and *Salmonella* using the nonwoven fabric sampler at different prewet volumes (n = 96). Data are presented for two surface types and two initial bacterial concentrations. Statistical differences between different treatments are denoted by compact letters over error bars at $P \leq 0.05$.

attachment capabilities of *Salmonella* and *L. monocytogenes* strains on distinct materials with smooth and nonsmooth surface structure (Lee & Pascall, 2017; Margas et al., 2014, Murphy et al., 2024; Silva et al., 2008; Verran et al., 2010) as well as cell surface and food-contact surface hydrophobicity affecting attachment and droplet surface area and relative drying time (Di Ciccio et al., 2015; De Cesare et al., 2003).

Characteristics of the surface sampler including design, material, and surface area can impact microbial recovery and release efficiency along with the condition of the food-contact surface (i.e., dry versus wet) as previously demonstrated for a variety of surface sampling tools (Keeratipibul et al., 2017; Jansson et al., 2020; Jones et al., 2020; Jones & Gibson, 2021, 2022). For instance, Orellana et al. (2024) reported significantly lower recovery of *L. monocytogenes* with nonwoven fabric samplers on SS, Teflon, and drain surfaces compared with PUF-based StickSponge™ samplers; however, the reason for lower recovery was driven by the use of nonpremoistened nonwoven fabric samplers. Indeed, when premoistened nonwoven fabric samplers were used, the recovery performances for the StickSponge™ and nonwoven fabric sampler were not significantly different (Pizzato, 2024). Similar increases in recovery efficiency have been reported when comparing wipes and swabs for which wipes achieved greater recovery percentages, potentially due to increased surface area and physical removal capabilities (Weir et al., 2016). Meanwhile, in the present study, the PUF sampler consistently yielded higher recovery percentages for PP surfaces for both *Salmonella* and *L. monocytogenes* compared with the cellulose sponge and nonwoven fabric samplers under all test conditions. However, these differences across samplers were not observed for the recovery of bacteria from SS surfaces. Overall, studies evaluating sampler performance have observed interactions between material

type, surface type, and microorganism type (e.g., between bacterial genera or between bacteria and virus) indicating there is no one-size-fits-all solution when it comes to surface sampler selection (Jansson et al., 2020; Jones et al., 2020; Jones & Gibson, 2022).

Inoculum level of the surfaces inconsistently impacted recovery percentage as shown in Figure 2, although the low inoculum level generally resulted in greater recovery for both *Salmonella* and *L. monocytogenes*. For instance, recovery percentage estimates mostly increased for *Salmonella* for both surface types and surface areas regardless of surface sampler type under low inoculum conditions compared to high inoculum experiments. The highest recovery of both *L. monocytogenes* and *Salmonella* occurred at low inoculum levels on PP surfaces with 10.2% and 4.56%, respectively (Fig. 2). The impact of inoculum level on recovery of microorganisms from surfaces has been investigated previously with mixed results (Weir et al., 2016; Jones et al., 2020). Notably, inoculum level has been shown to significantly impact bacterial transfer rates between surfaces (Montville & Schaffner, 2003) which is also applicable to the transfer of bacteria between the surface and sampling tool. The study authors showed a negative linear relationship between inoculum level and bacterial transfer between surfaces with lower inoculum levels achieving a significantly greater $\log_{10}$ percent transfer when compared to high inoculum levels. An additional study considered the effect of surface sampling factors (e.g., surface type, sampler type, inoculum level, and microorganism type) on a quantitative microbial risk assessment model for fomites and identified inoculum level as the parameter introducing the most variance to the model (Weir et al., 2016). These studies reiterate the inconsistent impact of inoculum level on bacterial recovery from surfaces and how various surface sampling tools perform.

In the present study, nonwoven fabric samplers represent a novel departure from the cellulose and PUF samplers which have relatively higher absorbance capacities due to their sponge-like structure. After prewetting the nonwoven fabric samplers, squeezing the sampler for removal of excess liquid similar to the sponge-like samplers was not very efficient in the present study. The material of the nonwoven fabric samplers left a reasonable amount of liquid on the surface after sampling despite presqueezing before sampling. This may be the reason for lower recovery of bacteria for certain combinations of factors when compared to the cellulose and PUF samplers (Fig. 2). Moreover, wearing the fabric sampler on fingers in sterilized gloves instead of swabbing via a plastic handle as with the sponge samplers provides the ability to put more pressure on the surface over larger areas during sampling but may also cause excessive liquid to be left on the surface. Because of this, the authors explored different volumes (5 and 10 mL) for premoistening the fabric samplers. The authors observed that the reduced volume (5 mL of PBS) for wetting the fabric samplers increased the recovery performance of both *Salmonella* and *L.* monocytogenes with a combined percentage of 10.66% when compared to 3.09% at 10 mL prewet volume (Fig. 3).

Additional factors in the present study may have affected the recovery success regardless of sampler type. First, the spot-inoculated surfaces were held in the biosafety cabinet for one hour before swabbing. It is important to mention that one hour is enough for attachment of *Salmonella* and *L. monocytogenes* cells onto the SS and PP surfaces (Purohit et al., 2020; Tadielo et al., 2022); however, not long enough for evaporation of liquid within the 25 μL droplets to have a dry surface. Thus, the state of the surface should be considered as a combination of wet and air-dried for this study which general supports higher recovery yields as reported previously (Lahou & Uyttendaele, 2014; Moore & Griffith, 2002). Also, all samplers used in the present study were premoistened as described by the manufacturer's instructions which may affect the recovery performance (Pizzato, 2024). Since all conditions including the sampling person were the same for all samplers in the present study, recovery comparisons between different types of samplers are considered acceptable.

Conclusions

There are several surface samplers designed for the food industry which utilize different shapes and sizes, various materials, and have different characteristics and recovery efficiency depending on the surface type, conditions, and structure. For instance, nonwoven fabric samplers seem practical for food contact surfaces with large areas, curves, and crevices. Also, the pressure for sampling on the surface can be increased when using the fabric samplers worn directly on gloved hands. Meanwhile, sponge-type samplers may offer a lower chance of cross-contamination due to an extended stick for handling and shape change capability providing higher efficiency to swab junctions and narrow spaces. With the data presented in the current study, it is recommended that selection of surface sampler should be based on the advantages and disadvantages of each product and the needs or goals of the environmental monitoring program within a given food production facility.

CRediT authorship contribution statement

Zeynal Topalcengiz: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Sahaana Chandran:** Writing – review & editing, Visualization, Formal analysis. **Francis Torko:** Writing – review & editing, Visualization, Formal analysis. **Kristen E. Gibson:** Writing – review & editing, Visualization, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: "This research was funded in part by FREMONTA, LLC. Moreover, this manuscript is intended as a third-party evaluation of the MicroTally® MicroMitt™ sampler and not a product endorsement.".

Acknowledgments

This research was funded in part by FREMONTA, LLC. This manuscript is intended as a third-party evaluation of the MicroTally® MicroMitt™ sampler and not a product endorsement. This research was also supported in part by the National Institute of Food and Agriculture (NIFA), U.S. Department of Agriculture (USDA) Hatch Act funding. We are grateful for the input and technical support from FREMONTA, LLC.

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