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Chemical Decontamination of Footwear Soles to Limit Microbial Transfer in a Dry Environment

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SUMMARY

Decontamination of footwear soles by chemical sanitizers is often used in food processing facilities to control the ingress of pathogenic microorganisms and their spread over floor surfaces, although little has been published to validate effectiveness. This study evaluated four decontamination treatments for efficacy in reducing microbial populations on footwear soles and for reducing transfer of those populations from soles to floors. Boot soles were inoculated with a mixture of equal parts of *Citrobacter freundii, Pseudomonas fluorescens,* and *Serratia marcescens,* donned, and subjected to treatment with aqueous quaternary ammonium sanitizer (Aqueous QAC, 1000 ppm) in a footbath mat, dry quaternary ammonium sanitizer (Dry QAC, 1.2% (wt/wt)) in a footbath mat, a spray of sanitizer containing 58.6% isopropyl alcohol and 150 ppm quaternary ammonium compounds (IPA QAC), and an IPA QAC spray followed by Dry QAC in a footbath mat (IPA QAC / Dry QAC). Before and after treatment, footwear soles and floor surfaces were sampled. No significant reductions in microbial populations on soles were observed upon treatment with Aqueous QAC, Dry QAC, compared with no treatment (control). Decontamination with IPA QAC and IPA QAC / Dry QAC resulted in 2.3 and 3.5 log reductions, respectively. Populations recovered from floor surfaces indicated IPA QAC and IPA QAC / Dry QAC treatments significantly reduced transfer of bacteria. Results of this study demonstrate that use of IPA QAC for decontamination of footwear may provide a significant barrier against the spread of microorganisms by foot traffic.

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INTRODUCTION

Safety of foods is often dependent on Good Manufacturing Practices (GMPs), including maintenance of manufacturing environments that prevent contamination of in-process or finished product materials. Accordingly, prevention of ingress and spread of pathogens into and among production areas is critical. Dedicated plant-only footwear can be used to prevent ingress of microorganisms from outside sources into the food processing environment; however, materials potentially contaminated with bacteria may be present inside the plant, including raw ingredients, raw in-process food materials and debris from facilities (e.g., floor sweepings, dust buildup). Procedures to sanitize footwear are widely used in the food industry as a GMP for preventing transfer of microorganisms from potentially contaminated areas to those where the product stream may be vulnerable.

Hygienic zoning provides barriers to contamination of product. Footwear sanitation contributes to these barriers by reducing the likelihood that pathogens can be transferred by footwear to floor surfaces in areas where microbial control is important for food safety. Although procedures such as footbaths are widely used in the food industry, very little information has been published that demonstrates a beneficial effect of chemical decontamination *(1, 9).* Footbaths require considerable costs for sanitizing chemicals and human resources to maintain. In some cases, footbaths can lead to more safety risk if not properly maintained *(4, 5). Listeria monocytogenes* was detected in a footbath located in a processed meat plant (F. Cook, unpublished data) in which the aqueous quaternary ammonium sanitizer contained particles of food debris. This poorly maintained footbath could then facilitate microbial spread rather than prevent it. Footbaths may also increase safety risks by introducing water to normally dry areas, increasing the potential for microbial growth and transfer.

The following study was done to evaluate four footwear decontamination treatments for reducing the potential for transfer of bacteria and to compare them for efficacy. Efficacy was determined by studying reduction of bacterial populations on boot sole surfaces as well as reduction of bacteria transfer from boots to floors following treatments.

MATERIALS AND METHODS

Study area

The study was conducted in a non-production location of a breakfast cereal manufacturing plant. The sealed concrete flooring in this area was thoroughly cleaned, using general purpose alkaline detergent (Restore LF, 2 oz/gal, Anderson Chemical, Litchfield, MN), rinsed with tap water, and disinfected with 70% denatured ethanol (Fisher Chemical, Pittsburgh, PA). Two treatment lanes (Fig. 1), 0.9 m × 6.5 m (3 ft × 21 ft) were delineated with red duct tape. Locations on the floor at three distances from the beginning of each lane (0.76 m (site 'a'), 3.4 m (site 'b'), and 6.5 m (site 'c') were marked with red duct tape. When treatment incorporated use of a footbath, a rubber footbath floor mat (81 cm × 99 cm × 6 cm) was placed in the lane 0.9 m from the beginning. All treatments, in addition to the control (untreated), incorporated the use of a 0.9 m × 0.9 m rug placed 1.75 m from the beginning. Rugs are often used in manufacturing plants to reduce risk of slippage after walking through a footbath.

Footwear

Work boots having two different tread patterns were used in the study. Boots categorized as having narrow treads had lugs that were comparatively more shallow and closer together than boots categorized as having wide treads (Fig. 2). Three identical boots of each category were used. Before use and after each trial of the study, footwear soles were cleaned and disinfected. Soles were immersed in water containing 600 ppm free available chlorine (Reg 13, Anderson Chemical, Litchield, MN) for at least 2 min, transferred to a solution of alkaline detergent (Restore LF, 2 oz/gal, Anderson Chemical, Litchfield, MN), manually brushed, rinsed thoroughly with tap water, and then dried with paper towels. Finally, footwear soles were sprayed with 70% denatured ethanol and allowed to dry completely. Microbiological sponge samples taken of boot soles after the cleaning and disinfection procedure were used to verify the effectiveness of each procedure for reducing microbial populations.

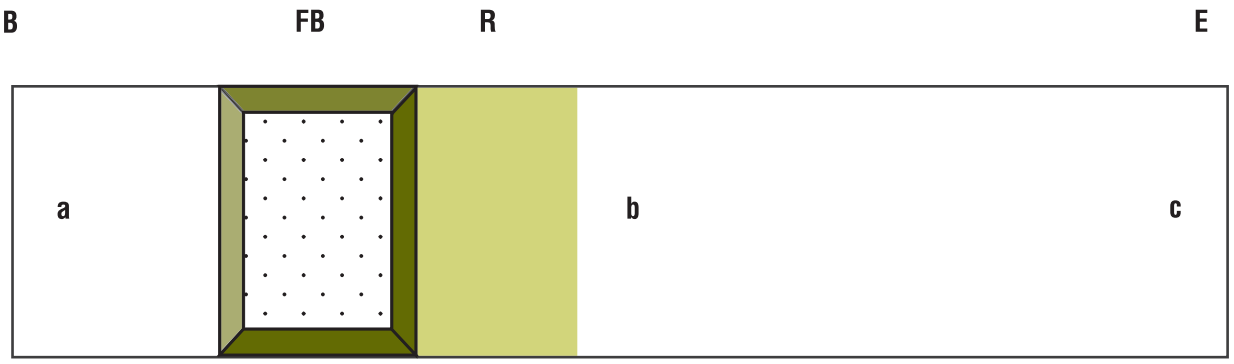

Figure 1. Depiction of the study treatment lane (0.9 m × 6.5 m) showing lane beginning (B), footbath (FB), rug (R), and lane end (E) locations

Figure 2. Wide (A) and narrow (B) tread pattern evaluated

Preparation of inoculum

Citrobacter freundii (lettuce isolate), *Pseudomonas fluorescens* (dairy isolate) and *Serratia marcescens* ATCC 14756 were used in this study. Strains obtained as frozen (-80°C) cultures in a 50% (vol/vol) glycerol solution were transferred to 10 ml of AOAC nutrient broth (BD Difco, Becton Dickinson, Sparks, MD). Following incubation at 35°C for 24 ± 4 h, cultures were transferred by loop to fresh AOAC nutrient broth. At least 3 but fewer than 15 consecutive laboratory transfers were made before these cultures were used in the study. For each day of the study a 24 ± 4 h culture was used to prepare a 1:1:1 (by volume) mixture of the cultures.

Inoculation of footwear soles

The inoculum suspension was transferred to an 88-ml capacity fingertip pump sprayer that delivered approximately 0.13 ml per pump as measured previously. Three sites on each sole (i.e., ball, arch, and heel) were inoculated by applying 1 pump of spray with the sprayer while the nozzle was held 5 ± 1 cm from the sole surface. Footwear was positioned sole-side-up and held for 20 min to allow for bacterial attachment prior to treatment.

Preparation of sanitizers

An aqueous quaternary ammonium chloride sanitizer (Aqueous QAC), dry quaternary ammonium chloride sanitizer (Dry QAC), and isopropyl alcohol-based quaternary ammonium chloride sanitizer (IPA QAC) were each evaluated. Aqueous QAC (1000 ppm QAC, Geron IV (a fifth-generation QAC), Anderson Chemical Co., Litchfield, MN) was prepared in tap water and its concentration verified by use of QAC test strips (LaMotte Co., Chestertown, MD). Dry QAC (Sani-Step, Ecolab Inc., St. Paul, MN) was a ready-to-use prill-based product containing 1.2% QAC wt/wt. IPA QAC (Alpet D2, Best Sanitizers Inc., Penn Valley, CA) was a ready-to-use sanitizer containing 58.6% IPA and 150 ppm QAC. Sanitizer products chosen were all EPA-registered and commercially available for use in food processing facilities.

Microbiological sampling and analysis

An experiment was performed to evaluate the effectiveness of cellulose-based sponges containing neutralizing solution (3M Sponge-Stick, St. Paul, MN) to recover the inoculum from footwear sole surfaces, and to evaluate recovery of microorganisms from the sponges. Briefly, the fingertip pump sprayer was used to dispense the inoculum into an empty sterile sample bag and a sterile sample bag containing a sponge (3M Sponge-Stick, St. Paul, MN). Comparison of populations recovered from each provides information on the release of microorganisms from sponges for quantification. Following the footwear sole inoculation procedure already described, sponges were used to recover microbial cells from both narrow-tread and wide-tread footwear. Entire sole surfaces, including grooves to the extent possible, were aggressively sampled using the sponges. Sampling efficiency (i.e., percent recovery) was determined as described by Moore and Griffith *(8):*

$$E = \left(\frac{N \times d}{1}\right) \times 100$$

Where E is the efficiency of the sampling technique, N the mean number of colony forming units, *D* the dilution factor, and *1* the number of colony forming units theoretically inoculated onto the swab or surface. This experiment was repeated three times.

Samples were shipped refrigerated (4–7°C) to Silliker Laboratories in Minnetonka, MN for bacterial enumeration. Upon receipt, 10 ml of Butterfield's buffer dilution water (BBL, Becton Dickinson, Sparks, MD) was added to each sample bag, which was stomached for 1 min. The resulting suspension was serially diluted and plated on 3M Petrifilm Aerobic Count Plate (3M Corp., St. Paul, MN), and plates were incubated for 48 ± 3 h at 35 ± 2°C prior to enumeration of survivors.

Footwear decontamination treatment procedure

The efficacy of four antimicrobial chemical treatments to reduce bacterial populations on footwear soles and to reduce bacterial transfer from soles to floors was evaluated. The same experimenter performed all treatments, including controls. Inoculated boots were donned at the beginning of the treatment lane without contacting the floor, and the left boot was sampled as described above. Each pass walking down the treatment lane consisted of 8 steps, always leading with the left boot. The floor area contacted by the first step of the right boot was designated as site 'a'. Decontamination treatment occurred on the second step of each boot, consisting of a footbath mat containing

Aqueous QAC, a footbath mat containing Dry QAC, spray of soles with IPA QAC (4 pumps / sole, or 3.9 ml), or spray of soles with IPA QAC (4 pumps / sole, or 3.9 ml), ensuring full coverage, before the experimenter stepped onto a footbath mat containing Dry QAC. The third step was onto a rug, and steps 4 through 8 were onto the sealed concrete floor following the rug. The floor areas contacted by the right boot of steps 4 and 8 were designated as sites 'b' and 'c', respectively. Without contacting any other surface after stepping onto floor site 'c', the right boot was swabbed to determine concentration of the inoculum. Floor sites a, b, and c (each approximately the size of the sole footprint (12.5 cm x 18 cm) were sampled. The duration of direct contact between the antimicrobial compound in footbath mats and boots was ca. 2 s. The time between exposure to treatment and sampling was 20 s. Direct contact exposure time was chosen to represent plant conditions in which workers walk through footbaths between hygienic zones without stepping in footbaths. The control treatments consisted of donning inoculated boots and walking over the treatment lane as described, without a decontamination treatment. Three passes using three different pairs of boots on separate areas of each lane as distinguished by red duct tape were made before the lane floor surfaces were cleaned with paper towels saturated with 70% ethanol (Fisher Scientific, Pittsburgh, PA) and disinfected by spraying with 70% ethanol. Random sampling of disinfected floor surfaces was conducted to confirm the efficacy of the procedure in removing interfering flora between treatment replicates.

Decontamination of wet footwear soles to limit microbial transfer

At times, floor conditions in some areas of food manufacturing facilities may be wet. A study was done to evaluate the efficacy of IPA QAC in reducing bacteria on wet footwear soles and in reducing microbial transfer from wet footwear soles to floors. Thirty milliliters of inoculum was prepared as described and transferred to a shallow sanitized container holding approximately 6 liters of phosphate buffered saline (PBS, pH 7.2). The resulting suspension was mixed to distribute the inoculum evenly. Approximately 10 ml was collected at the beginning and end of the study on each day of testing to confirm consistent microbial levels. To inoculate footwear soles, re-usable rubber footwear covers were donned by an experimenter who stepped into the container so that the suspension contacted the sole surfaces of the footwear for 30 s. The experimenter stepped out of the inoculum suspension container, took one step with each shoe, and sat in a chair without further floor contact, at which time the left footwear sole was sampled for microbial levels. The right footwear sole was then sprayed with IPA QAC (4 pumps of a trigger spray bottle, ca. 3.9 ml), ensuring full coverage, and was sampled after 20 s of exposure with the sanitizer. This was repeated 5 times, using a new pair of footwear covers each time. The study was done on each of two days.

To determine the efficacy of IPA QAC spray treatment for reducing transfer of bacteria from wet footwear soles to floors, the experimenter donned reusable rubber footwear covers and stepped into the inoculum container as described. After 30 s, the experimenter stepped out of the suspension container and took one step with each shoe; then the right footwear sole was sprayed with IPA QAC (4 pumps, ca. 3.9 ml), ensuring full coverage. The experimenter then took five additional steps and sat in a chair without further floor contact, at which time the right and left footwear soles were sampled 20 s after IPA QAC treatment. One minute after treatment, floor surfaces were sampled where the first and fifth steps had contacted the floor (sites b and c, respectively). Microbial counts recovered from floor surfaces contacting the left shoe (no treatment, control) and the right shoe (IPA QAC treatment) were compared. This was repeated 5 times, using a new pair of footwear covers each time. The study was done on each of two days.

Neutralization control

Effectiveness of the neutralizing medium used to moisten the cellulose sponges for microbiological sampling in quenching the activity of QAC was evaluated. Cleaned and disinfected footwear was pre-moistened with tap water and donned by the experimenter. Boot soles were driven into dry QAC contained within a footbath floor mat to capture the dry QAC material within the treads of boots. Dry QAC was collected onto a sterile sponge, which was placed back into its sample bag. After massaging the dry QAC into the sponge, sponges where inoculated by delivering 0.13 ml of the inoculum suspension into each bag, using the finger pump sprayer. Control samples were prepared by inoculating sponges not exposed to the dry QAC material. Previous study investigating the amount of dry QAC carried by boot soles after stepping into a floor mat of the material showed that this treatment provided substantially more QAC (mg) onto sponges than any other treatment investigated and was worst case in terms of the chemical burden to effective neutralization.

Statistical analysis

Colony forming units were enumerated from Petrifilm and data of survivors enumerated from footwear soles, and those recovered from floor sample sites were transformed to log units. Means were determined from triplicate samples of each combination of treatment or control and footwear tread style. Log reductions on soles were calculated by determining the difference in populations recovered from the pre-treatment (left) boot versus the post-treatment (right) boot. Means of log reductions and of cells recovered from floor sample sites were calculated. An analysis of variance and the Tukey comparison test were used to analyze means by MiniTab16 (MiniTab, Inc., State College, PA). Each treatment was done three times on each of three different days.

RESULTS AND DISCUSSION

Inoculum recovery from footwear soles

An experiment was conducted to determine the sampling efficiency of the cellulose-based sponges used in the study to recover the inoculum from footwear soles after inoculation and drying for 20 min. *Figure 3* summarizes these data. Populations recovered from direct inoculation of sponges within sample bags were similar to those enumerated from sample bags without sponges (7.94 log CFU and 7.99 log CFU, respectively) suggesting that the sample analysis technique employed sufficiently released recovered cells from sponges for plating. Approximately 6.49 log CFU were recovered from footwear soles, and recovery from footwear with narrow treads was similar to recovery from footwear with wide treads. Based on these data, sampling efficiency

of the cellulose-based sponges for recovering the inoculum from footwear soles was 3.5%. Moore and Griffith *(8)* reported lower sampling efficiencies of four different types of sampling devices when they attempted to recover *E. coli* that had been onto stainless steel coupons. In their evaluation of composite tissue (cellulose-based wipes) to recover *L. monocytogenes* from stainless steel, Vorst et al. *(15)* presented data supporting a sampling efficiency of approximately 1.9%. Composite tissue was determined to yield the best recovery of the four sampling devices evaluated.

Disinfection control of footwear and floor surface

Following each trial consisting of inoculation, treatment, and sampling, footwear was cleaned, disinfected, and reinoculated for subsequent treatment and sampling. The results of tests of efficacy of the cleaning and disinfection procedure are presented in Fig. 3. Populations were reduced by 3.0 – 4.3 log CFU as a result of the procedure. After each of the three repeated passes of footwear decontamination treatment, the treatment lane was cleaned, disinfected, and sampled. The average population recovered from sample sites on disinfected floors throughout the study was 1.48 log CFU. Inoculation at high cell density (8.28 log CFU/sole) was employed to enable quantification of treatment efficacy and microbial transfer onto floors in light of the background microflora remaining on boots after cleaning and disinfection as well as the microflora associated with floors.

Efficacy of decontamination in reducing populations on footwear soles

Microbial reductions resulting from the four decontamination treatments evaluated are presented in Fig. 4. Under the exposure parameters described, Aqueous QAC and Dry QAC treatment resulted in 0.59 and 0.22 log reductions, respectively, which fell within the same statistical grouping (Tukey's Test, $P \leq 0.05$) as the reduction observed following no treatment (the control). Log reductions in populations on footwear followed by treatment with IPA QAC and IPA QAC followed by Dry QAC were significantly different ($P \leq 0.05$) from reductions after the other treatments and the no-treatment control. IPA QAC spray resulted in a 2.34 log CFU reduction, whereas the treatment incorporating both an

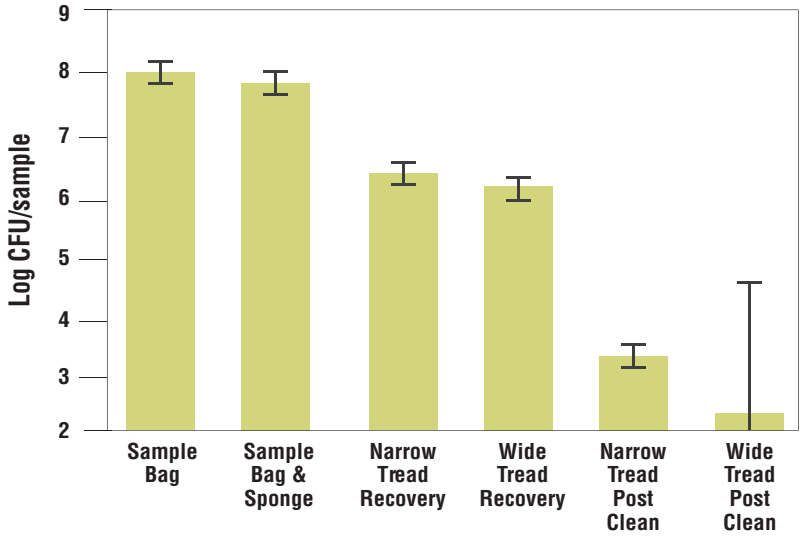

Figure 3. Populations (log CFU/sample) of a multi-species Gram-negative inoculum recovered from sample bags, sample bags including a sponge, sponges following sampling narrow-tread boots, sponges following sampling wide-tread boots, and sponges following sampling inoculated narrow- and wide-tread boots after cleaning and disinfection. Interval bars represent 95% CI for the means

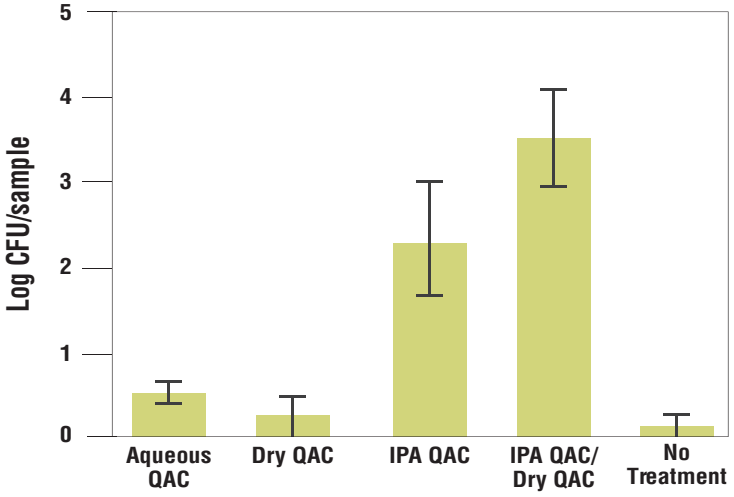

Figure 4. Log CFU reductions of a multi-species Gram-negative inoculum associated with footwear sole surfaces as a result of treatment with aqueous QAC, Dry QAC, IPA QAC and IPA QAC / Dry QAC. Interval bars represent 95% CI for the means

IPA QAC spray and Dry QAC achieved a 3.54 log CFU reduction. The latter treatment was significantly ($P \leq 0.05$) more biocidal than the former. No difference in microbial recoveries from identically treated boots was observed between boots with narrow treads and those with wide treads (data not shown).

Du et al. *(2)* evaluated the efficacy of Aqueous QAC and IPA QAC in reducing *Salmonella* in dust associated with almond hulling and shelling facilities. No change in *Salmonella* populations was reported upon exposure to Aqueous QAC (200 ppm) for 10–15 min, whereas populations were reduced to levels below the limit of detection (1.3 log CFU/g) by treatment with IPA QAC (>3.9 log reduction). This study demonstrated marked biocidal activity of IPA QAC in the presence of a substantial organic challenge.

Dry QAC treatment alone did not significantly impact populations of footwear soles. Dry QAC is a water-activated sanitizer, and the presence of at least some moisture is required to allow for interaction between the QAC molecule and the target microorganism. When soles were moistened with IPA QAC before Dry QAC treatment, microbial reduction and resulting impact to transfer of microorganisms to floors was significant. In dry processing environments, the use of IPA QAC may serve as an alternative to water or water treated with an antimicrobial agent to pre-moisten footwear soles for activation of Dry QAC in a subsequent treatment. Although use of Dry QAC increased effectiveness of IPA QAC, carry-over of Dry QAC by footwear traffic from mats to floors was observed and may be undesirable in some processing environments.

Aqueous QAC treatment in this study did not result in a significant microbial reduction following exposure. Exposure time was chosen to represent conditions of use in plants where workers walk through QAC solutions in footbaths without pausing for a determined exposure time. QAC product labels typically describe directions for use in footbaths and other entryway sanitizing systems. The minimum exposure time included in the directions originates from studies required for U.S. Environmental Protection Agency registration to support inanimate, non-food contact sanitizing claims, where the performance requirement is at least a 99.9% (3 log) reduction in bacterial count within 5 min of contact between cells dried onto a surface (e.g., stainless steel) and the sanitizer solution *(15).* Many product labels list a minimum exposure time shorter than 5 min (e.g., 1 min) in footbath applications. However, this duration of contact between worker's footwear and sanitizer is not practical in practice. Results of this study suggest that inadequate sanitization occurs on footwear soles having brief exposure time typical of workers who walk through footbaths without stopping. The degree of chemical-based bactericidal activity increases with longer contact times *(6).* The requirement for a standardized dwell time of footwear soles in footbaths containing Aqueous QAC may be necessary to ensure adequate microbial lethality and control of transfer.

Microbial transfer to floors

Microbial populations recovered from floor surface sites before and after footwear decontamination treatment are presented in Table 1. Populations were compared within each footwear decontamination treatment procedure. The two treatments incorporating use of IPA QAC led to significantly ($P \leq 0.05$) lower counts at sites 'b' and 'c' compared to 'a' (prior to treatment), which correlated with log reductions determined on boot soles. Treatment with Aqueous Quat or Dry Quat alone in footbaths did not significantly affect microbial populations

TABLE 1. Populations (log CFU/sample) of a multi-species Gram–negative inoculum recovered from floor surfaces one step prior (a), two steps after (b), or five steps after (c) footwear sole decontamination treatment[b]

	Footwear decontamination treatment				
Floor Sample Site	Aqueous QAC Bath	Dry QAC Bath	IPA QAC Spray	IPA QAC Spray & Dry QAC Bath	No Treatment (control)
A	2.96[a]	2.68[a]	2.85[a]	3.38[a]	3.03[a]
B	2.69[a]	2.44[a]	2.21[b]	2.08[b]	2.37[a]
C	2.44[a]	2.35[a]	2.14[b]	1.98[b]	2.35[a]

[a]Step = approximately 0.8 m
[b]Within columns, means not followed by the same letter are significantly different ($P \leq 0.05$).
Initial cell density on footwear soles was 6.49 log CFU/sole.

recovered from floor sites following exposure, although in all cases counts generally decreased from site 'a' to site 'b' to site 'c'. Comparing means among the four treatments and control across the individual floor sample sites revealed no significant ($P \leq 0.05$) difference in populations.

Evaluation of counts from sampling the left boot prior to treatment and counts from floor site 'a' prior to treatment enables the determination of a transfer rate, the percentage of cells transferred from the donor surface (boot sole) to the recipient surface (floor) *(10).* Because distribution of transfer rate data is generally non-normal, transformation to log transfer rate is recommended *(10).* Non-transformed transfer rate data in this study was distinctly right-skewed. A transfer rate of 100% (complete transfer and recovery of cells from the donor surface to the recipient surface) would equal a log transfer rate of 2.00. The log transfer rate determined at site 'a' in this study (89 observations) was -1.43 (approximately 0.037% transfer). This transfer rate agrees with rates reported by Montville and Schaffner *(7)* at similar donor cell density, but is lower than transfer rates generally reported elsewhere *(10, 13)* involving several different food and inanimate substrates. Factors influencing transfer rate have been described *(7, 10, 12, 13)* and in this study might include tread pattern, as not all tread surfaces came into contact with the floor, as well as the nature of compression or shear force in the act of walking, the presence of moisture or debris along with microorganisms, etc. Although the number of observations provided in this study enabled the determination of a transfer rate at floor site 'a', evaluating factors contributing to that rate was not an objective of the work.

Decontamination of wet footwear soles to limit microbial transfer

Treatment of wet footwear soles with IPA QAC resulted in a 1.48 log reduction of bacteria associated with sole surfaces, whereas treatment of dry footwear with IPA QAC resulted in a 2.34 log reduction. The lower log reduction of bacteria on wet soles may be attributed to dilution of the active sanitizing components (isopropyl alcohol and quaternary ammonium compounds) upon mixing with the moisture on sole surfaces. Treatment of wet footwear soles with IPA QAC reduced microbial transfer to floors (Fig. 5). Populations of bacteria recovered from floor sites 'b' and 'c' after contacting treated and non-treated footwear soles were compared. Deposition of bacteria from treated footwear soles was significantly less ($P < 0.05$) than deposition from non-treated footwear soles at both floor sites. Moreover, at floor site 'c', populations recovered after contacting treated footwear soles were similar ($P = 0.97$) to the background microflora level, indicating that numbers of bacteria transferred to this site by soles may have been less. Log CFU reduction by IPA QAC spray treatment on sole surfaces after floor contact was 1.88 and was not significantly different ($P = 0.15$) from the log reduction determined on soles not contacting floor surfaces.

In their research to determine mechanisms of *Salmonella* contamination in an oil meal processing facility, Morita et al. *(9)* concluded that exclusion of personnel from processing floors of protected environments was effective in impeding the spread of the pathogen. When foot traffic was not controlled and passage was allowed, *Salmonella* was detected on sampled floor surfaces within two weeks. Where foot traffic cannot be restricted for the sake of product manufacture, chemical sanitization of footwear is employed to reduce the likelihood of spread of pathogens. Results of this study demonstrate that use of IPA QAC sanitizer reduces populations of microorganisms on footwear soles and microbial transfer from soles to floors. Because IPA QAC sanitizer readily evaporates, the presence of moisture in the immediate environment of footwear sanitization is reduced in comparison to the use of footbaths containing Aqueous QAC, which are often accompanied by rugs in dry processing environments to wick away moisture from boots and to reduce slip-and-fall risk after use. Rugs themselves can become saturated and the potential for QAC loss due to interaction with anionic moieties associated with fibers *(3)* should be considered. If not adequately maintained, footbaths can harbor microorganisms and can contribute to rather than reduce spread of microorganisms *(4, 5).* Because of the low flash point of IPA QAC, safety matters must be considered when it is being used. Storage and disposal should comply with local fire authorities.

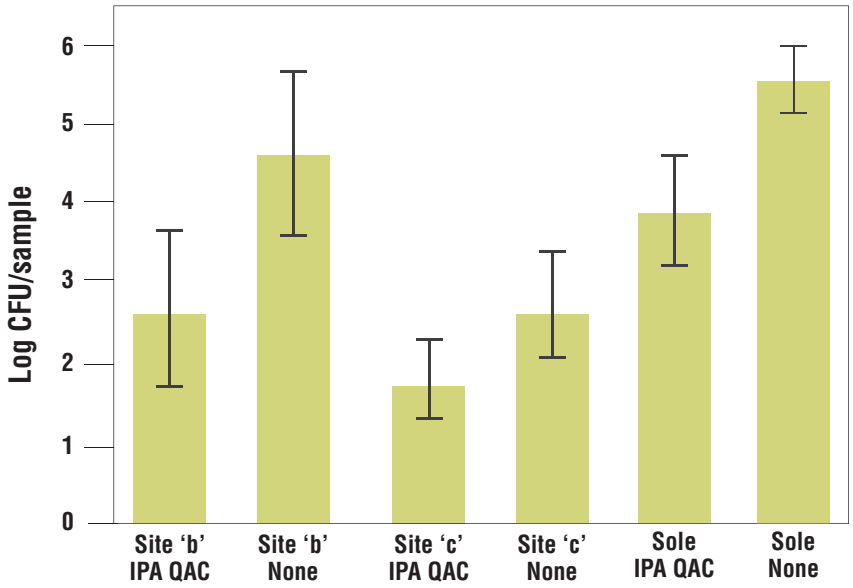

Figure 5. Populations (log CFU/sample) of a multi-species Gram-negative inoculum recovered floor sample sites 'b' and 'c' (one and five steps, respectively, following treatment) and from wet footwear sole surfaces as a result of treatment with IPA QAC. Interval bars represent 95% CI for the means

RECOMMENDATIONS

Where personnel traffic cannot be eliminated, chemical decontamination of footwear soles incorporating use of IPA QAC can reduce transfer of microorganisms to processing floors. IPA QAC may be more effective than Aqueous QAC when used under brief exposure conditions, and may also be advantageous for maintaining facilities in a drier condition, reducing risks associated with microbial growth and transfer.

REFERENCES

1. Ayliffe, G. A. J., B. J. Collins, and E. J. L. Lowbury. 1967. Ward floors and other surfaces as reservoirs of hospital infections. *J. Hyg.* 65:515–536.

2. Du, W., M. D. Danyluk, and L. J. Harris. 2009. Efficacy of aqueous and alcohol-based quaternary ammonium sanitizers for reducing *Salmonella* in dusts generated in almond hulling and shelling facilities. *J. Food Sci.* 75:M7–M13.

3. Grieme, L. G., K. T. Thompson, H. L. Carbone. 2009. Evaluation of quat absorption and efficacy of cleaning cloths. APIC Annual Conference, Ft. Lauderdale, FL.

4. Langrud, S. T. Moretro, and G. Sundheim. 2003. Characterization of *Serratia marcescens* surviving in disinfecting footbaths. *J. Appl. Microbiol.* 95:186–195.

5. Langsrud, S., L. Seifert, and T. Moretro. 2006. Characterization of the microbial flora in disinfecting footbaths with hypochlorite. *J. Food Prot.* 69:2193–2198.

6. Merianos, J. J. 2001. Surface-active agents. p. 283–320. *In* S. S. Block (ed.), Disinfection, sterilization, and preservation, 5th ed. Lippincott Williams & Wilkins, Philadelphia, PA.

7. Montville, R., and D. W. Schaffner. 2003. Inoculum size influences bacterial cross contamination between surfaces. *Appl. Environ. Microbiol.* 69:7188–7193.

8. Moore, G., and C. Griffith. 2007. Problems associated with traditional hygiene swabbing: the need for in-house standardization. *J. Appl. Microbiol.* 103:1090–1103.

9. Morita, T., H. Kitazawa, T. Lida, and S. Kamata. 2006. Prevention of *Salmonella* cross-contamination in an oilmeal manufacturing plant. *J. Appl. Microbiol.* 101:464–473.

10. Perez-Rodriguez, F., A. Valero, E. Carrasco, R. M. Garcia, and G. Zurera. 2008. Understanding and modeling bacterial transfer to foods: a review. *Trends Food Sci. Technol.* 19:131–144.

11. Podolak, R., E. Enache, W. Stone, D. G. Black, and P. H. Elliot. 2010. Sources and risk factors for contamination, survival, persistence, and heat resistance of *Salmonella* in low-moisture foods. *J. Food Prot.* 73:1919–1936.

12. Rodriguez, A., W. R. Autio, and L. A. McLandsborough. 2007. Effects of inoculation level, material hydration, and stainless steel roughness on the transfer of *Listeria monocytogenes* from inoculated bologna to stainless steel and high-density polyethylene. *J. Food Prot.* 70:1423–1428.

13. Sattar, S. A., S. Springthorpe, S. Mani, M. Gallant, R. C. Nair, E. Scott, and J. Kain. 2001. Transfer of bacteria from fabrics to hands and other fabrics: development and application of a quantitative method using *Staphylococcus aureus* as a model. *J. Appl. Microbiol.* 90:962–970.

14. U.S. Environmental Protection Agency. 1976. Sanitizer test for inanimate surfaces, DIS/TSS-10 efficacy data requirements. Available at: http://www.epa.gov/oppad001/dis_tss_docs/dis-10.htm. Accessed 3 March 2011.

15. Vorst, K. L., E. C. D. Todd, and E. T. Ryser. 2004. Improved quantitative recovery of *Listeria monocytogenes* from stainless steel surfaces using a one-ply composite tissue. *J. Food Prot.* 67:2212–2217.