Comparison of Swiffer Wipes and Conventional Drag Swab Methods for the Recovery of Salmonella in Swine Production Systems

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ABSTRACT

The main goal of this study was to assess the efficacy of Swiffer wipes in comparison to conventional drag swabs for the recovery of Salmonella. A total of 800 samples (400 Swiffer wipes and 400 drag swabs) were aseptically collected from randomly selected swine barns before disinfection with specific biocides and within 2 h after disinfection. From each barn, 10 samples of each swab type and negative controls were collected. Salmonellae were isolated from 43 (10.8%) of 400 drag swabs and 34 (8.5%) of 400 Swiffer wipes. There was a significant reduction in Salmonella postdisinfection as identified with both sampling procedures irrespective of the type of biocide used (P < 0.05). With the drag swabs, salmonellae were detected in 15% of the samples before disinfection versus 6.5% after disinfection, whereas with the Swiffer wipes, 13 and 4% of the samples were positive pre- and postdisinfection, respectively. Of the total 720 fecal samples collected from pigs placed in the disinfected barns, 132 (18.3%) were Salmonella positive. About 65 and 98% of the Salmonella isolates from swine barns and fecal samples, respectively, were resistant to one or more of the antimicrobials tested. Multidrug resistance was found in 35.7% of the isolates from barn swabs and 56.4% of the isolates from fecal samples. Results of this study suggest that the conventional drag swab method results in better recovery of Salmonella than does the Swiffer wipe method and thus could be a useful sampling method in monitoring Salmonella. Pentaresistant Salmonella (mainly R-type ACSSuT) was more common in fecal samples than in environmental samples.

Among domestic food animals, swine are considered one of the important Salmonella carriers and thus can be a source infection in the production and processing environment. Salmonella cells can survive in the swine environment for long periods (1) and can serve as a source of infection to other animals and humans. Salmonella enterica serovars that are commonly associated with swine are among the major foodborne human health problems in the United States (7). The high prevalence and dissemination of antimicrobial-resistant pathogens such as nontyphoidal Salmonella, particularly those strains that are multidrug resistant (MDR), have become public health concerns worldwide and are frequently a focus of discussion (12, 16). The emergence of Salmonella strains of food animal and environmental origin that are resistant to clinically important antimicrobial agents such as fluoroquinolones and third generation cephalosporins also has been a major issue in recent years (20).

Monitoring the efficacy of cleansing and disinfection procedures in swine farms and the impact of such practices on the reduction of foodborne pathogens such as Salmonella is important. For implementing Salmonella monitoring programs in the food animal production environments, an environmental sampling method that is convenient to apply in the field, is cost-effective, and results in better recovery of Salmonella is required. Other researchers have reported the results of different sampling methods for the detection of Salmonella in the poultry production environment (2, 4, 5, 18). Burgess and colleagues (3) reported the efficacy of Swiffer wipes as part of a swab sample technique for the detection of Salmonella environmental contamination in a veterinary teaching hospital. However, little is known about the efficacy of different sampling methods for the detection of Salmonella in the food animal production environment where the types of interventions could be quite different from those used in hospitals. The purpose of this study was to assess the efficacy of Swiffer wipes (Proctor and Gamble, Cincinnati, OH) as compared with conventional drag swab sampling methods for the recovery of Salmonella in the swine production environment before and after disinfection of swine barns. We also analyzed the status of Salmonella in fecal samples and the antimicrobial resistance profiles of isolates collected from swine kept in those disinfected barns.
SWINE ENVIRONMENT SAMPLING METHODS FOR SALMONELLA

MATERIALS AND METHODS

Study design and sample collection. The present study is part of an investigation of the role of specific classes of biocides and heavy metal micronutrients in the occurrence and persistence of MDR Salmonella in the swine production environment. The study was conducted from October 2007 to January 2008 in three vertically integrated conventional swine production systems that were recruited conveniently; three farms per system and four barns per farm were selected randomly. Four interventions were applied: three biocides (Bioentry [Bioentry, Inc., Stone Mountain, GA], Synergize [Preserve International, Reno, NV], and VirkonS [Antee International, Suffolk, UK]) and pressurized hot water (control). These treatments were used to regularly disinfect assigned swine barns during the study period. Barns were randomly assigned to one of the three disinfectant treatments (0.4% Bioentry, 1% VirkonS, and 33% Synergize), with the hot water treatment as a control. Each barn was washed and cleaned with high-pressure water before disinfection with the assigned disinfectant or hot water. Applications of the disinfectants to all barns were conducted by a single person using the same type of pressure wash equipment. A total of 800 environmental samples (400 Swiffer wipe samples and 400 drag swab samples) representing each of the production systems, farms, and biocidal interventions were aseptically collected. Samples were collected predisinfection and postdisinfection but before pigs were placed in each of the disinfectant barns. Approximately 30 min to 2 h elapsed between disinfection (or control hot water wash) and collection of floor swabs from the barns. This interval allowed the disinfectants to act and the floor surface to become moderately dry.

Ten Swiffer wipe samples, 10 drag swab samples (Tyco Healthcare/Kendall, Mansfield, MA), and negative control samples (pre- and postdisinfection) were collected from each barn simultaneously following previously described methods (3, 11). Sterile drag swabs were moistened with 10 ml of buffered peptone water (BPW; Becton Dickinson, Sparks, MD). The free end of the string was grasped and swabs were opened out while holding them up away from the pen floor. The swabs were laid onto the chosen slat and pulled along, making sure to not allow the swabs to fall between the slats and proceeding toward the inner alleyway. Once the inner edge of the pen is reached, the swabs were elevated and laid on a different slat. The swabs were pulled back toward the outer wall making sure not to step on the slat being swabbed. The swabs were picked up by the string and carefully placed inside sterile Nasco Whirl-Pak sample collection bags (Zefon International, Ocala, FL). Swiffer wipes were taken from the box with a gloved hand, and the designated area (not sampled with the drag swabs) facing out and was placed in a Whirl-Pak bag. After labeling the bag with the pen number and whether the sample was collected pre- or postdisinfection, the bag was sealed, placed in a cooler with ice packs, and shipped to the laboratory for analysis. One Swiffer wipe and one drag swab were used per pen at each stage of disinfection. Within 7 to 10 days of placement of pigs in each disinfected barn, fecal samples (48 samples per barn) were aseptically collected from individual pigs per rectum with a gloved hand. Samples were placed in sterile Whirl-Pak bags, transported to the laboratory on ice, and processed for Salmonella isolation within 24 h.

Salmonella isolation. Salmonella was isolated and identified following conventional methods as described previously (10–12). A 10-g fecal sample was preenriched in 90 ml of BPW and incubated at 37°C overnight. Ninety milliliters of BPW also was added to each bag containing the drag swabs and Swiffer wipes and incubated at 37°C for overnight. About 100 μl of the preenriched sample was added to 9.9 ml of Rappaport-Vassiliadis enrichment broth (Becton Dickinson) and incubated at 42°C for 24 h. A loopful of this culture was plated onto xylose lysine tergitol 4 (XLT4; Becton Dickinson) agar plates and incubated at 37°C for a minimum of 24 h. Three isolated colonies from these plates were selected, and each isolate was inoculated into triple sugar iron agar slants and urea broth (Becton Dickinson) and incubated at 37°C overnight. Those positive isolates were identified to serogroup using commercially available polyvalent O and group-specific antisera (Mira Vista, Copenhagen, Denmark).

Antimicrobial susceptibility testing. Antimicrobial susceptibility of Salmonella isolates from Swiffer wipes, drag swabs, and fecal samples were tested against a panel of 12 antimicrobials using the Kirby-Bauer disc diffusion method as recommended by the NCCLS (19) and as described previously (10, 12, 13). The following antimicrobials and disc concentrations were used: 10 μg of ampicillin, 30 μg of amoxicillin–clavulanic acid, 30 μg of amikacin, 30 μg of ceftiraxone, 30 μg of cephalothin, 30 μg of chloramphenicol, 5 μg of ciprofloxacin, 10 μg of gentamicin, 30 μg of kanamycin, 10 μg of streptomycin, 250 μg of sulfisoxazole, and 30 μg of tetracycline. Escherichia coli ATCC 25922, Enterococcus faecalis ATCC 29212, Staphylococcus aureus ATCC 25923, and Pseudomonas aeruginosa ATCC 27853 were used as controls. Isolates with intermediate zones of inhibition were considered susceptible. Each isolate that was resistant to three or more classes of antimicrobials was classified as MDR.

Data analysis. Statistical analysis was done with the SPSS statistical software package (SPSS, Chicago, IL). Prevalence of Salmonella, serogroups, and antimicrobial resistance profiles were analyzed at the barn and pig levels. The primary unit used to compare the efficacy of the two swabbing methods was the barn level. The chi-square test statistic was used to determine the significance of the reduction of Salmonella postdisinfection, and results with a P value of <0.05 were considered significant.

RESULTS AND DISCUSSION

Salmonellae were isolated from 43 (10.8%) of 400 drag swabs and 34 (8.5%) of 400 Swiffer wipe samples collected from swine barns (Table 1). There was a significant reduction of Salmonella in the postdisinfection samples with both sampling procedures regardless of the type of biocide used to disinfect the barns (P < 0.05). With the drag swab method, salmonellae were detected in 15% of the samples predisinfection and 6.5% postdisinfection. With the Swiffer wipes sampling method, 13 and 4% of the samples were positive for Salmonella at pre- and postdisinfection, respectively (Fig. 1). There are no published data on the comparative performance of Swiffer wipes and conventional drag swabs for the detection of Salmonella in the swine production environment; many of the available data are specific to poultry farms. Results of this study indicate that the conventional drag swabs are more efficient than the Swiffer wipes for recovery of Salmonella both before and after disinfection of barns regardless of the biocide used. The reasons for the more sensitive detection of Salmonella with the drag swabs compared with the Swiffer wipes are not clear. The difference might be partly associated with differences in the recommended protocols. Drag swabs are
TABLE 1. Salmonella recovery from swine barns before and after disinfection with different classes of biocides

<table>
<thead>
<tr>
<th>Biocide</th>
<th>No. of barns</th>
<th>Drag swab (n = 400)</th>
<th>Swiffer wipe (n = 400)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Predisinfection</td>
<td>Postdisinfection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(n = 200)</td>
<td>(n = 200)</td>
</tr>
<tr>
<td>Biosentry</td>
<td>6</td>
<td>11/60</td>
<td>2/60</td>
</tr>
<tr>
<td>Synergize</td>
<td>5</td>
<td>10/50</td>
<td>3/50</td>
</tr>
<tr>
<td>VirkonS</td>
<td>5</td>
<td>4/50</td>
<td>2/50</td>
</tr>
<tr>
<td>Hot water (control)</td>
<td>4</td>
<td>5/40</td>
<td>6/40</td>
</tr>
<tr>
<td>Total, no. (%)</td>
<td>20</td>
<td>30 (15)</td>
<td>13 (6.5)</td>
</tr>
</tbody>
</table>

FIGURE 1. Comparison of Salmonella recovery achieved with Swiffer wipes and conventional drag swabs before and after disinfection of barns and recovery from fecal samples collected from pigs placed in those barns.

premoistened with BPW, whereas the Swiffer wipes function via electrostatic system thus are used dry. As shown in the current study, the electrostatic mechanism was not as efficient for Salmonella recovery as were the moistened regular drag swabs. The cost of prepackaged sterile drag swabs was much lower than that of the Swiffer wipes. The gauze sponges used to prepare the drag swabs in this study were $0.03 each, whereas the Swiffer wipes were $0.28 each.

None of the disinfection procedures used completely removed Salmonella from the swine barns, suggesting the need for multiple intervention procedures at different stages or perhaps more stringent disinfection protocols. The prevalence of Salmonella per barn ranged from 0 to 63% before disinfection and 0 to 18% after disinfection. Even though the disinfection process greatly reduced the level of Salmonella, as indicated by the low recovery rate with both sampling methods after disinfection, complete clearance of the pathogen from the barns was not achieved with the cleaning and disinfection procedures applied. In previous studies, salmonellae were detected on pen floors of swine commercial production operations despite thorough cleansing and disinfection of the sites (8, 14). Salmonella can persist in the environment for long periods (1), and thus contamination may not be completely removed using routine cleaning and disinfection procedures. Even though stringent cleansing and disinfection procedures in the swine production environment can provide a cleaner environment for the pigs, Salmonella enterica control on pigs farms in general requires multiple approaches (9, 17).

Of the total 720 fecal samples collected from the three vertically integrated conventional production farms, 132 (18.3%) were positive for Salmonella (Fig. 1). The prevalence of Salmonella per barn ranged from 0 to 83.3%. More than 80% of the isolates belonged to serogroups B (62%) and C (20%) regardless of origin (feces or swabs) (Fig. 2). The proportion of serogroup C isolates was significantly higher in environmental samples than in fecal samples. About 65 and 98% of the Salmonella isolates from swine barns and fecal samples, respectively, were resistant to one or more of the antimicrobials tested. Significantly more pansusceptible Salmonella isolates were recovered from the barn swabs (35% of the isolates) than from the fecal samples (2% of the isolates). The most plausible explanation for this finding is that a higher proportion of serogroup C isolates was detected from the swab samples than from the fecal samples. Members of Salmonella serogroup C, e.g., Braenderup, Mbandaka, and Oranienburg, which have been isolated commonly from pigs in this study area (12), often tend to exhibit pansusceptible patterns. All isolates from the environment (including those from drag swabs and Swiffer wipes) and the swine were susceptible to ciprofloxacin, ceftriaxone, and amikacin. In isolates from swine barn samples and fecal samples, a high frequency of antimicrobial resistance was detected to tetracycline (60.3

FIGURE 2. Distribution of Salmonella serogroups isolated from swine barn environmental swab samples and fecal samples.
and 96.2%, respectively), streptomycin (39.6 and 76.3%), sulfisoxazole (31 and 61.4%), ampicillin (37.3 and 66.2%), chloramphenicol (24.6 and 34%), and kanamycin (11 and 32.7%). In previous studies conducted in this study area, the common occurrence of antimicrobial resistance to various antimicrobials was reported, including those antimicrobials for which resistance was found also in the present study (10, 12, 13). One of the consequences of antimicrobial use in food animals, including swine, is the development of antimicrobial-resistant foodborne pathogens such as Salmonella and the potential transmission of these pathogens to humans through contaminated food products (15).

MDR isolates were more common in fecal samples than in environmental samples ($P < 0.05$): 35.7% (45 of 126) and 56.4% (212 of 376) of the isolates from swine barn samples and fecal samples, respectively, had an MDR profile. We propose two possible explanations for this finding. First, the lack of antimicrobial selective pressure in the barn environment compared with the gastrointestinal tract of the pigs coupled with the fitness burden imposed on MDR strains could allow the less resistant strains (often not serogroup B) to prevail on the barn floor. The second possible explanation could be variation in tolerance to disinfectants among various Salmonella serogroups and strains. Although the design of this study did not enable us to definitely determine which explanation is correct, a study addressing this issue is currently underway. Nevertheless, these findings are consistent with our previous findings in swine production units (6). No qualitative difference was found in antimicrobial resistance phenotypes of Salmonella isolates from swine farm samples and Swiffer wipes. The isolates from swine barn samples and fecal samples were most commonly resistant to ampicillin, chloramphenicol, streptomycin, sulfisoxazole, and tetracycline (R-type ACSSuT) with or without resistance to amoxicillin–clavulanic acid, cephalothin, kanamycin, or gentamicin. This MDR pattern was commonly detected in both fecal samples (30.3%; 114 of 376 isolates) and swab samples (23%; 29 of 126 isolates). Another common MDR profile exclusively detected in isolates from fecal samples was R-type AmKmSuTe (13%; 49 of 376 isolates), which was found only in samples from one barn. Resistance to streptomycin, sulfisoxazole, and tetracycline (R-type SSuT) was found in 10.3% (13 of 126) and 12.5% (47 of 376) of the isolates from the environmental swab samples and fecal samples, respectively. The MDR patterns detected in this study were reported previously in swine and swine production environments in this study area and these production systems (6, 10, 12, 13).

Results of this study suggest that the conventional drag swab method results in more accurate recovery of Salmonella from the swine production environment than does the Swiffer wipe method and thus could be a useful sampling method for monitoring Salmonella in swine production environment. Salmonellae are widespread in swine and the swine production environment, and strains can be recovered more frequently from swine fecal samples than from swine production environmental samples. A qualitative difference was found in phenotypes (serogroups and antimicrobial resistance patterns) of Salmonella isolated from swine and from the swine production environment. A significant reduction in Salmonella contamination was found after disinfection of the barns; however, many of the barns remained positive for Salmonella, suggesting the need for multiple interventions at different stages. Resistance to multiple antimicrobials, including ampicillin, chloramphenicol, streptomycin, sulfisoxazole, and tetracycline, was common among the isolates from both fecal and environmental samples but in different proportions.

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**REFERENCES**


