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Research Paper

In-Plant Validation Study of Harvest Process Controls in Two Beef Processing Plants in Honduras

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ABSTRACT

Imported meat in the United States can become a food safety hazard if proper food safety programs are not fully implemented in foreign meat processing plants. Thus, exporting countries' food safety inspection systems must be equivalent to the U.S. federal inspection system to become eligible to export meat to the United States. The objective of this study was to validate the beef harvest Hazard Analysis and Critical Control Points and food safety programs of two beef processing plants in Honduras operating under U.S. equivalency standards by evaluating the presence of *Salmonella* (plant A) and Shiga toxin–producing *Escherichia coli* (STEC; plant B) on hides. Additionally, evaluating pathogen transfer from hides to carcasses, as detected by preevisceration sampling, and the mitigation of transferred pathogens, by application of carcass spray interventions and determination of *Salmonella* presence in lymph nodes, was also conducted. In plant A, the presence of *Salmonella* on hides ($n = 30$ of 687; 4.4%) was significantly greater ($P < 0.10$) than on carcasses swabbed at preevisceration ($n = 7$ of 687; 1.0%), after intervention ($n = 13$ of 678; 1.9%), and in lymph nodes ($n = 14$ of 691; 2.0%). In plant B, *Salmonella* was not detected on hide samples; therefore, data could not be used for validation of the harvest Hazard Analysis and Critical Control Points program. Alternatively, STEC presence on hides ($n = 21$ of 85; 24.7%) was greater ($P < 0.10$) than on carcasses at preevisceration ($n = 3$ of 85; 3.5%) and after intervention ($n = 1$ of 85; 1.2%). Pathogen presence in plant B did not differ ($P = 0.306$) between carcasses in preevisceration and postintervention stages; both, however, were substantially low. Both plants' controls effectively reduced *Salmonella* and STEC presence in postintervention carcasses.

Key words: Beef harvest; Equivalency, Honduras; *Salmonella*; Shiga toxin–producing *Escherichia coli*; Validation

Salmonella and Shiga toxin–producing *Escherichia coli* (STEC) are naturally found in the gastrointestinal tract of cattle *(19)*. Although they usually do not cause visible illness in cattle, they can cause illness in humans. Together, these pathogens are annually responsible for one million illnesses, approximately 21,800 hospitalizations, and 400 deaths in the United States *(22)*. In beef processing facilities, cattle entering from the external environment can carry pathogens onto the harvest floor *(1, 17)*. Once inside the plant, pathogens can spread to carcasses and can be difficult to eliminate *(23)*. To mitigate pathogen transfer to carcasses and subsequently to final products, meat processing plants implement a variety of food safety programs, including Sanitation Standard Operating Procedures (SSOP), Good Manufacturing Practices (GMP), Sanitation Performance Standards (SPS), and Hazard Analysis and Critical Control Points (HACCP).

In 2016, beef and veal imports to the United States totaled 3 billion lb from 93 different countries *(9)*. Imported meat can become a food safety hazard if proper food safety programs are not implemented in meat processing plants. Thus, the federal government requires that any foreign facility that intends to export any meat product to the United States meet equal food safety standards through a process known as "equivalence." This implies that U.S. Department of Agriculture (USDA) Food Safety Inspection Service (FSIS) must inspect and approve both the facilities' food safety practices and the government's inspection system *(26)*.

"Validation" is the process of ensuring that the interventions applied and the overall HACCP plan will control the food safety hazards identified in the product *(14)*. Implementation of GMP and SPS should be effective to prevent pathogen transfer and cross-contamination during different steps in the harvest process. Validation of these practices to reduce pathogens will help the processing plants ensure these are being implemented properly, ultimately validating their overall HACCP plan, as has been demonstrated by our group in the past *(6, 17)*.

Honduras' food regulatory system has recently acquired equivalency status for export to the United States,

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with beef exports increasing to 960.5 tons (ca. 831,351 kg) from 2016 to 2017 *(9)*. Before an individual plant can export its products to the United States, it needs to show evidence of the validation of their harvest HACCP program and critical control points and that it can successfully implement such a program *(5)*. We hypothesized that the plants' harvest process controls would mitigate and reduce STEC and *Salmonella* presence on postintervention carcasses, and therefore, the objective of this study was to validate the beef harvest HACCP and food safety programs of two individual beef processing plants in Honduras operating under U.S. equivalency standards by estimating the presence of *Salmonella* and STECs on hides and carcasses and by evaluating the mitigation of pathogens by the application of spray interventions. Plants were not compared with each other as the location, breeds, diets, numbers of animals, interventions, and microorganisms used for validation were different and independent of each other.

MATERIALS AND METHODS

Plant descriptions. Two different meat processing plants in Honduras were sampled. Both plants wanted to create export markets for their meat in the United States. Plant A was located at Siguatepeque (Comayagua state, Honduras) in the central-western region of the country. This region of Honduras has a rainy season starting in approximately April and ending in December. The dry season in the region lasts from December to April. Plant A harvests approximately 900 head of cattle per week and has 490 employees. The hot-carcass intervention before chilling consisted of peracetic acid spray at 50 to 100 ppm. The antimicrobial intervention was applied with a manual backpack pump with an extended nozzle to reach all areas of the carcasses. Peracetic acid solution was applied until the entire surface of the carcass was covered. Immediately after the intervention, the carcasses went into the chiller, where the postintervention samples were taken after they had stopped dripping solution. Concentration of peracetic acid was verified with a peracetic acid titration kit.

Plant B was located at Catacamas (Olancho state, Honduras), in the eastern region of the country. This region of Honduras has rainy season between May and November. The dry season in the region is approximately between the months of November and May. Plant B harvests approximately 450 heads of cattle per week and has 210 employees. The hot-carcass intervention before chilling consisted of a lactic acid solution spray at 2.0 to 2.5%. The antimicrobial intervention was applied with a backpack pump. Lactic acid solution was applied until the entire surface area of the carcass was covered. After applying the antimicrobial intervention, the carcasses went into the chiller and were sampled when they had stopped dripping solution. The concentration of lactic acid was verified with a titration kit.

Sample collection. In plants A and B, microbiological carcass samples were taken from lymph nodes, hides, and carcasses located during preevisceration and postintervention steps. *Salmonella* presence was evaluated in plant A, whereas the presence of both *Salmonella* and STEC was evaluated in plant B. Because of concerns and ramifications of potential positive results, plant A refused to allow us to test for STEC during the sampling period when we conducted the study.

Subiliac lymph nodes were excised after hide removal and placed into 24-oz (ca. 710-cm^3) unfiltered Whirl-Pak bags (Nasco, Fort Atkinson, WI). Hide swab samples were taken after exsanguination and before hide removal. Carcass swab samples on preevisceration were taken immediately after hide removal. No interventions were applied to the carcass between the de-hiding and the evisceration process. Postintervention carcass swab samples were taken after hot-carcass intervention from each plant, immediately after the carcass stopped dripping solution and before chilling it. All carcass microbiological samples were taken by swabbing the foreshank and brisket areas with EZ-Reach Sponge Samplers (World Bioproducts, Mundelein, IL) with 25 mL of buffered peptone water. Samples were immediately placed in insulated bags and kept cold with previously frozen ice packs. Insulated bags containing the samples were transported by air to the Texas Tech University Food Microbiology Laboratory in Lubbock for microbiological analysis. Transportation and customs clearance (U.S. Animal and Plant Health Inspection permit no. 114031) were granted beforehand by USDA-FSIS. Samples in plant A ($n = 2{,}743$) were taken as follows: 687 hide samples, 687 preevisceration samples, 678 postintervention samples, and 691 lymph nodes. In plant B ($n = 255$), we obtained 85 hide samples, 85 preevisceration samples, and 85 postintervention samples for microbial analysis. Samples were taken on the same carcass throughout its stages in the harvest floor. All samples from plant A underwent *Salmonella* detection and isolation procedures. Samples in plant B underwent both *Salmonella* and STEC detection and isolation procedures as explained below.

Sample preparation. Hide preevisceration and postintervention samples were homogenized in a stomacher (model 400 circulator, Seward, West Sussex, UK) at 230 rpm for 30 s. From each swab sample, 1 mL was transferred to 9 mL of modified tryptic soy broth with 8 mg/L novobiocin and acid digest of casein (Neogen, Lansing, MI), which was incubated at 42°C for 24 h.

Microbiological analysis. *Salmonella* detection and isolation were performed with a modification of the USDA-FSIS protocol *Microbiology Laboratory Guidebook* (MLG) section 4.09 *(12, 28)*. Preevisceration and postintervention carcass-sample enrichments were analyzed by BAX system PCR assay *Salmonella* detection kits (Hygiena, Camarillo, CA). From each hide and positive PCR samples, 1 mL of modified tryptic soy broth was transferred to 9 mL of Rappaport-Vassiliadis (RV) broth (Oxoid, Hampshire, UK) and 1 to 9 mL of tetrathionate broth (Neogen, Lansing, MI). Both RV and tetrathionate broths were incubated at 42°C for 18 to 24 h. Enrichments of RV and tetrathionate were then streaked onto xylose lactose Tergitol 4 (Hardy Diagnostics, Santa Maria, CA) with 1-μL sterile loops and incubated for 40 to 48 h at 37°C. Presumptive *Salmonella* colonies were initially confirmed by agglutination with the Wellcolex Color *Salmonella* Agglutination Kit (Thermo Fisher Scientific, Lenexa, KS). Positive agglutinating colonies were subjected to real-time PCR confirmation for *Salmonella*. Real-time PCR was done targeting the *ttrC* gene *(16)*.

Lymph nodes were processed and analyzed for detection and isolation of *Salmonella* as previously described by Brichta-Harhay et al. *(2)*. Lymph nodes were trimmed to remove excess fat. The weight of each lymph node was recorded. The outside surface of each lymph node was sterilized by immersing in boiling water for 3 to 5 s. Lymph nodes were pulverized with a rubber mallet inside a 24-oz (ca. 710-cm^3) filtered Whirl-Pak bag (Nasco) and then homogenized with 80 mL of TSB in a stomacher (model 400 circulator, Seward) at 230 rpm for 2 min. Lymph node bags were then incubated for 2 h at 25°C, 12 h at 42°C, and 6 h at 4°C. Composites of five samples were made from the enriched lymph nodes and then tested by immunomagnetic separation with anti-

TABLE 1. Salmonella *presence in lymph nodes and on hides and preevisceration and postintervention carcasses on every sampling date from 2015 through 2017*

			Percentage (no./total)			
Year	Sampling time	Seasonality	Hides	Preevisceration carcasses	Postintervention carcasses	Lymph nodes
2015	Feb.	Dry	2.9 (1/34)	2.9 (1/34)	5.9 (2/34)	20.6 (7/34)
2015	Apr.	Rainy	5.6 (7/125)	4.0 (5/125)	6.0 (7/116)	0.0 (0/124)
2015	Jun.	Rainy	17.0 (8/47)	0.0 (0/47)	4.3 (2/47)	8.5 (4/47)
2015	Aug.	Rainy	14.3 (5/35)	0.0 (0/35)	0.0 (0/35)	0.0 (0/40)
2015	Nov.	Rainy	3.8 (8/210)	0.0 (0/210)	0.0 (0/210)	0.5 (1/210)
2016	3 Feb.	Dry	0.0 (0/39)	0.0 (0/39)	0.0 (0/39)	0.0 (0/39)
2016	29 Feb.	Dry	0.0 (0/38)	0.0 (0/38)	0.0 (0/38)	0.0 (0/38)
2016	Apr.	Rainy	0.0 (0/18)	0.0 (0/18)	0.0 (0/18)	0.0 (0/18)
2016	Aug.	Rainy	0.0 (0/78)	0.0 (0/78)	0.0 (0/78)	1.3 (1/78)
2017	Jan.	Dry	1.6 (1/63)	1.6 (1/63)	3.2 (2/63)	1.6 (1/63)

Salmonella Dynabeads (Thermo Fisher Scientific), following the manufacturer's instructions. The resulting cell suspension was transferred to 3-mL RV-broth tubes and incubated at 42°C for 18 to 20 h. Afterward, RV broth was streaked onto xylose lysine deoxycholate (Remel, St. Louis, MO) and brilliant green sulfa agar (Difco, BD, Sparks, MD) and incubated at 37°C for 24 h. Colonies with black centers in xylose lysine deoxycholate and bright pink colonies on brilliant green sulfa agar were considered presumptively positive for *Salmonella,* which was confirmed by agglutination with the Wellcolex agglutination kit. Positive agglutinating colonies were subjected to real-time PCR confirmation for *Salmonella,* targeting the *ttrC* gene.

For plant B's samples, STEC detection was conducted following the MLG 5B.05 protocol for detection and isolation of non-O157 STEC *(27)*. Composites of five samples each were made for preevisceration and postintervention samples. Preevisceration and postintervention composites were subjected to BAX screening kits for *stx* and *eae* genes. Samples of composites that were positive on screening were then run individually through BAX screening kits for *stx* and *eae* genes. Composites of two hide samples were created by adding 1 mL of each of the enrichments of the two samples into a sterilized tube. Hide composites and individual positive-screening preevisceration and postintervention samples were subjected to the BAX system STEC panels 2 and 1 and O157 kits for detection with the Big 7 STEC kit (Hygiena). Positive samples in BAX had their individual samples undergo immunomagnetic separation for positive STECs with panels 1 and 2 and O157 kits. From the resulting cell suspension, 30 μL was streaked onto modified rainbow agar (Biolog, Hayward, CA) supplemented with 0.05 mg of cefixime trihydrate, 0.150 mg of potassium tellurite, and 5 mg of novobiocin per L. Presumptive-positive STEC colonies on modified rainbow agar were confirmed by latex agglutination test kits (Abraxis Inc., Warminster, PA) corresponding to the presumptive-positive serogroup. Positive agglutinating colonies are considered presumptive positives by the FSIS guidelines; therefore, all STEC isolates were presumptively positive for STEC in this study.

Statistical analysis. The statistical analysis was performed in R (version 3.4.4, R Foundation for Statistical Computing, Vienna, Austria) statistical package. A χ^2 comparison was used when comparing the presence of each pathogen among types of samples. For each individual plant, odds ratios comparing hide pathogen incidence to carcasses in preevisceration and postintervention samples were estimated and reported. Because the objective of the study was to validate the process controls for each individual plant, no comparisons between plants A and B were attempted because of differences in, among other factors, interventions, regions, types of animals, and sampling dates. Statistical differences were calculated on a 0.10 probability threshold. Seasonality variation of *Salmonella* presence in plant A was evaluated by χ^2 analysis comparing its presence in rainy months against dry months; the rainy season was considered April through December, whereas the dry season was considered to be January through March.

RESULTS AND DISCUSSION

Plant A. Because of its low STEC presence, *Salmonella* data for plant A were used to validate the harvest HACCP plan. Presence of *Salmonella* was evaluated for the years of 2015, 2016, and the beginning of 2017, with 10 individual sampling dates. *Salmonella* presence varied throughout sampling dates (Table 1). Results from χ^2 analysis for plant A (Table 2) demonstrated that *Salmonella* presence on hides (30 of 687; 4.4%) was greater ($P < 0.10$) than it was in lymph nodes (14 of 690; 2.0%) and on postintervention (13 of 678; 1.9%) and preevisceration (7 of 687; 1.0%) carcasses. In fact, odds ratios indicated that

TABLE 2. *The χ^2 analysis and odds ratios of hide* Salmonella *presence compared with lymph nodes and preevisceration and postintervention carcasses*

Sample analyzed	χ^2 test statistic	*P* value	Odds ratio	90% confidence interval
Hide vs preevisceration carcasses	14.693	<0.001	4.44	2.21–8.90
Hide vs postintervention carcasses	6.71	0.01	2.34	1.34–4.06
Hide vs lymph nodes	6.106	0.013	2.21	1.29–3.79

TABLE 3. *Overall pathogen presence for plants A and B*

Plant (pathogen test)	Percentage (no./total)[a]			
	Hides	Preevisceration carcasses	Postintervention carcasses	Lymph nodes
Plant A (*Salmonella*)[b]	4.37 (30/687) A	1.0 (7/687) B	1.9 (13/678) B	2.0 (14/691) B
Plant B (STEC)[b]	24.7 (21/85) X	3.5 (3/85) Y	1.2 (1/85) Y	NA[c]

[a] Columns within a row with different letters are statistically different ($P < 0.10$).
[b] No statistical comparison between the plants was conducted, and they cannot be compared with each other because the data represent different pathogens (*Salmonella* and STEC).
[c] NA, for plant B, no STEC analysis was conducted on lymph nodes.

Salmonella presence on hides was 4.44 times greater than it was on preevisceration carcasses, 2.34 times greater than it was on postintervention carcasses, and 2.21 times greater than it was in lymph nodes, and the latter three sampling descriptions did not differ with *Salmonella* presence ($\chi^2 = 2.5811$, $P = 0.2751$). Overall presence of *Salmonella* in plant A throughout the sampling period is provided in Table 3.

Interventions are applied to reduce and mitigate pathogen presence *(3)*. However, no intervention, by itself, can completely ensure the elimination of pathogens every time it is implemented. Several interventions are currently applied within the meat industry trying to eliminate pathogens from carcasses. These include organic acid sprays, trimming, washing, steam vacuuming, and a combination of other chemical compounds, such as citric acid with ascorbic and erythorbic acids. Both plants sampled had implemented trimming as a critical control point to comply with the zero tolerance of visible material, ingesta, or milk. Additionally, each plant implemented carcass washing with water at room temperature before the final hot-carcass intervention. Moreover, both plants had fully implemented SSOP and GMP throughout the harvest procedure. Previous studies have reported significant reductions of *Escherichia coli* O157:H7 (between 3.2 and 4.4 log CFU/g) when trimming visible fecal contamination, depending on the carcass sampling site *(13)*. Similarly, reductions of total microbial counts on carcasses after trimming of 3.0 log CFU/g have been found *(21)*. Carcass washing is used as a usual practice of the harvest procedure in a beef processing plant, aimed at removing bone dust or foreign material from trimmed carcasses. Furthermore, carcass washing has also been reported to reduce microbial load. Average reductions of 1.8 log CFU/g of *E. coli* O157:H7 were achieved after tap water wash treatment had been applied to beef carcasses *(8)*. Application of hot-water rinse can achieve reductions of 2.0 to 3.5 log CFU/g *(13)*. Likewise, increasing wash-water temperature can reduce the time required for water exposure. Significant reductions of 2.1 log CFU/g during washing with water at 165°F (ca. 73.9°C) for 20 s were achieved *(7)*. However, if not applied properly, carcass washing has been observed to spread contamination to all the carcass surfaces *(11)*. Reductions of 1.0, 1.7, and 2.6 log CFU/g have been achieved with lactic acid spray washing concentrations of 1, 3, and 5%, respectively *(18)*. Similarly, pathogen reductions varying from 1.3 to 2.7 log CFU/g with lactic acid spray have been observed *(4)*. A previous study by our group has shown that the use of antimicrobials has resulted in reduction of the presence of non-O157 of up to 90% in some cases *(6)*. Peracetic acid interventions have been proven to reduce *E. coli* O157 when applied at 180 ppm, where it reduced almost 4 log CFU of contamination from beef and veal carcass surfaces *(20)*. In other instance, peracetic acid at 200 ppm was used as an intervention during the spray-chilling process, where it achieved a 1.5-log CFU reduction of *E. coli* O157:H7 *(24)*. Interventions of peracetic acid and lactic acid have been compared in previous studies in which both interventions have reduced *E. coli* O157:H7 and *Salmonella* concentrations; however, lactic acid has proven to be more effective than peracetic acid as a carcass intervention *(15)*.

A significant reduction of *Salmonella* presence when comparing hide to carcass samples indicates proper procedures are being implemented to reduce pathogen transfer and, therefore, reduce risk of contamination in final products. Dehiding procedures are effective at preventing *Salmonella* transfer from hides to carcasses. Furthermore, on the first three sampling dates, *Salmonella* was more frequently found on postintervention carcasses. Recommendations for adequate conditions for intervention applications were provided and subsequent sampling demonstrated that *Salmonella* presence was reduced. Because of process controls applied on the harvest floor and correct dressing procedures, the *Salmonella* presence was significantly reduced (Table 3).

Presence of *Salmonella* on hides varies throughout the year, as observed on Table 1. Thus, seasonality effect over *Salmonella* was evaluated. A χ^2 analysis was performed for the presence of *Salmonella* during rainy season (28 of 513; 5.5%) and dry season (2 of 174; 1.1%) throughout 2015 to 2017. *Salmonella* presence in plant A varied by season ($P < 0.10$), and a significantly greater presence was found during rainy season. A seasonality effect on *Salmonella* presence in cattle fecal samples has been observed, in which cattle shed *Salmonella* at a much lower frequency during winter months in the United States *(10)*.

Plant B. Sampling in plant B for the in-plant validation study of harvest procedures was conducted on six different dates. The number of samples collected varied because of total animals harvested and was adjusted on the basis of pathogen presence detected on previous sampling dates. No *Salmonella* was detected in any of the hide samples ($n = 85$). Because hide samples serve as baseline for pathogen

TABLE 4. *Presence of STECs on hides and preevisceration and postintervention carcasses on sampling dates*

		Percentage (no./total)		
Year	Sampling time	Hides	Preevisceration carcasses	Postintervention carcasses
2017	15 Feb.	0.0 (0/10)	0.0 (0/10)	0.0 (0/10)
2017	28 Feb.	13.3 (2/15)	0.0 (0/15)	0.0 (0/15)
2017	15 Mar.	30.0 (3/10)	10.0 (1/10)	10.0 (1/10)
2017	17 Mar.	25.0 (5/20)	5.0 (1/20)	0.0 (0/20)
2017	22 Mar.	20.0 (3/15)	6.7 (1/15)	0.0 (0/15)
2017	26 Jul.	53.3 (8/15)	0.0 (0/15)	0.0 (0/15)

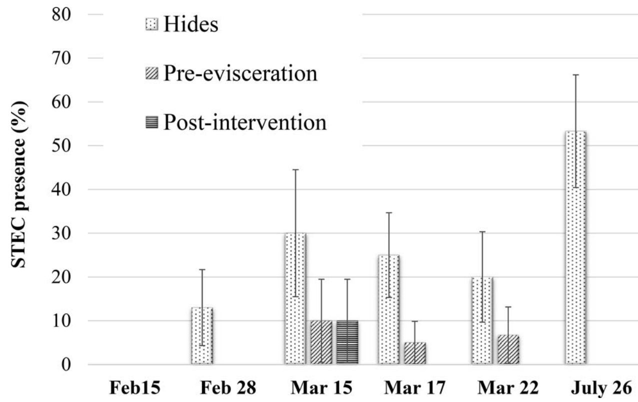

FIGURE 1. *Presence of STECs on hides and preevisceration and postintervention carcasses on six sampling dates of 2017 for plant B.*

transfer, *Salmonella* data could not be used for validation of the harvest HACCP program. However, STEC presence varied among sampling dates (Table 4). The χ^2 analysis results for plant B (Table 5) indicated that STEC presence on hides (21 of 85; 24.7%) was more frequent ($P < 0.10$) than it was on preevisceration (3 of 85; 3.5%) and postintervention (1 of 85; 1.2%) carcasses. Furthermore, the presence of STEC on hides was 8.97 times greater than it was on preevisceration carcasses and 27.56 times greater than on postintervention carcasses. A χ^2 STEC comparison between preevisceration and postintervention carcasses showed nonsignificant differences ($\chi^2 = 1.048$, $P = 0.306$). Presence of STEC on preevisceration and postintervention carcasses was not significantly different ($P = 0.3281$) than 0, indicating that the presence of STEC on carcasses was very low. Overall presence of STECs in plant B can be observed in Table 3. Pathogen reduction from hide to carcass was observed on almost every sampling date (Fig. 1).

GMPs should be fully implemented to have adequate dehiding procedures, and those procedures must include sanitizing of harvesting knives *(25)* to prevent cross-contaminations among carcasses. The significant reduction of STEC on preevisceration carcasses indicates good dehiding practices, showing that GMPs were correctly implemented. Furthermore, the reduction of STEC presence on postintervention carcasses indicates that no cross-contamination with these pathogens occurred. Activities performed on the harvest floor efficiently reduced pathogen presence and the eventual transfer to postintervention carcasses.

Pathogen transfer from hide to carcass was low in both plants, as indicated by 1.0% *Salmonella* presence on preevisceration carcasses in plant A and 3.5% STEC presence on preevisceration carcasses in plant B. That low rate of presence suggests adequate dressing procedures for reducing carcass contamination from hides. Interventions implemented on the harvest floor reduced STEC presence on postintervention carcasses to 1.2% in plant B. In contrast, plant A pathogen presence on postintervention carcasses was 1.9%. Most *Salmonella* presence on postintervention carcasses (11 of 13; 84.6%) from plant A was found on the first three sampling dates. After those findings, recommendations for harvesting conditions and verification of the concentration of acidic solutions (50 to 100 ppm of peracetic acid spray) were provided to the plant. A two-knife system was implemented in which one knife was used for different cuts on a carcass, whereas the other knife was in the knife sterilizer; the knives were then switched between carcasses, which has been validated as helpful in a previous study by our research group *(25)*. Additionally, the plant employee in charge of performing the titration on the antimicrobial intervention solution was trained and shown how to perform corrective actions for increasing or diluting the concentration of the peracetic acid. The plant made significant investments in new equipment to replace old and obsolete equipment that could have served as a potential niche for contamination, and they renovated the harvest floor. Subsequent samplings demonstrated that, even though preevisceration carcasses were positive for the pathogen, a reduction was achieved in postintervention carcasses (0% positive for the last three samplings) after initial recommendations were followed and implemented, which were consistent with previous results obtained by our group *(17)*.

Understanding seasonality of enteric pathogen shedding is important to reinforcing cleaning and disinfection protocols as well as dehiding and dressing procedures. At a time of high pathogen shedding, slower line speeds and sampling should be conducted to ensure proper mitigation of pathogens in carcasses and process control. Mitigation of pathogen entrance into the processing environment is of utmost importance to reduce pathogen presence in finished products. Monitoring of pathogen presence on carcasses and

TABLE 5. *A χ^2 analysis and odds ratios of hide STEC presence compared with preevisceration and postintervention carcasses*

Sample analyzed	χ^2 test statistic	P value	Odds ratio	90% confidence interval
Hide vs preevisceration carcasses	15.719	<0.001	8.97	3.13–25.67
Hide vs postintervention carcasses	20.885	<0.001	27.56	5.01–151.71

products is necessary throughout a period of higher pathogen shedding from the cattle.

In summary, both plants' interventions reduced pathogen presence on postintervention carcasses efficiently. *Salmonella* and STEC presence on beef carcasses can be mitigated by the process controls implemented in Honduran plants. Overall, sanitary conditions and GMP and HACCP interventions on the harvest floor, effectively controlled and reduced pathogen presence on processed beef carcasses. Hide-to-carcass pathogen transfer was significantly mitigated, and the resulting pathogen presence on carcasses after microbial intervention with peracetic acid in plant A and lactic acid in plant B was substantially low. After validation of their harvest HACCP programs, both plants became eligible foreign establishments certified to export meat to the United States as part of the equivalency process.

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