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Salmonella and *Campylobacter* prevalence and concentration on pasture-raised broilers processed on-farm, in a Mobile Processing Unit, and at small USDA-inspected facilities

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ABSTRACT

The small-scale, pasture-raised poultry production model is a growing niche in the locally grown food movement. Research that focuses on the food safety of small-scale broiler processing methods is limited. The objective of this study was to compare *Salmonella* and *Campylobacter* prevalence and concentrations on pasture-raised broilers processed on-farm, in a small United States Department of Agriculture – Inspected slaughter facility (USDA-IF), and in a Mobile Processing Unit (MPU) pilot plant. A total of 120, 100, and 50 post-chill, pasture-raised broiler carcasses were sampled from each processing method, respectively. Pathogen prevalence and concentrations from whole carcass rinses were determined using a 3-tube Most Probable Number (MPN) method for *Salmonella* and direct plating method for *Campylobacter* according to the USDA-Food Safety and Inspection Service (FSIS) protocols. Both *Salmonella* prevalence and concentrations on-farm (89% and 1.78 MPN/carcass [95% CI: 1.60–1.96]), USDA-IF (43% and 0.78 MPN/carcass [95% CI: 0.58–0.98]) were significantly ($P < 0.05$) different. *Salmonella* was not detected on carcasses processed via the MPU. *Campylobacter* prevalence was not significantly ($P > 0.05$) different on carcasses processed by the three methods (70% on-farm, 82% USDA-IF, and 100% MPU). The mean $\log_{10}$ *Campylobacter* concentrations in MPU processed carcasses (5.44 $\log_{10}$ CFU/carcass [95% CI: 5.24–5.63]) was significantly higher ($P < 0.05$) compared to on-farm (2.32 $\log_{10}$ CFU/carcass [95% CI: 2.06 –2.80]) and USDA-IF (2.44 $\log_{10}$ CFU/carcass [95% CI: 2.03–2.85]). Based on the results of this baseline study, most pasture-raised broilers processed by the three methods were contaminated with *Salmonella* and/or *Campylobacter*. Further research is needed to assess other potential risk factors such as farm and regional variations that may contribute to the differences in pathogens' prevalence and concentrations.

1. Introduction

Limited research exists that focuses on the food safety of small-scale pasture-raised broiler production systems. The current available data on specialty market poultry (i.e. non-conventionally raised birds) has reported the prevalence of pathogens such as *Salmonella* and *Campylobacter* at the farm, processing, or retail level (Alali, Thakur, Berghaus, Martin, & Gebreyes, 2010; Esteban, Oporto, Aduriz, Juste, & Hurtado, 2008; Hanning, Biswas, Herrera, Roesler, & Ricke, 2010; Heuer, Pedersen, Andersen, & Madsen, 2001; Lund, Welch, Griswold, Endres, & Shepherd, 2003; McCrea et al., 2006; Melendez et al., 2010; Siemon, Bahnson, & Gebreyes, 2007; Van Loo, Alali, & Ricke, 2012; Van Overbeke, Duchateau, Zutter, Albers, & Ducatelle, 2006). However, data on the microbial loads of such pathogens on pasture-raised broiler carcasses do not exist to the best of our knowledge.

Consumer interest in sustainable agriculture has resulted in an increased demand for locally produced products (Johnson, Marti, & Gwin, 2012). A growing niche in the locally grown food movement is the pastured poultry production model. Batches of 50–90 chicks are introduced into floorless pens that are rotated to fresh pasture

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on a daily basis to encourage forage intake (Salatin, 1993). Consumers and producers are drawn to this production model based on the expectation of improved flavor and nutrition of the meat, animal welfare, soil fertility, sustainability of the farm environment and community involvement (Fanatico, 2012; Hillmire, 2011).

Access to a profitable retail market for locally raised poultry meat requires a USDA-inspected status for which many small-scale producers are ineligible. Therefore, these producers face substantial barriers to economic feasibility of their operations. Farmers often process their birds at the site of production (on-farm), in a Mobile Processing Unit (MPU), or birds are transported to a small USDA-inspected slaughter facility (USDA-IF) that will process a limited number of custom batches of birds (O'Bryan, Gibson, Crandall, & Ricke, 2012). The absence of regulatory guidance along with the relative scarcity of studies on small-scale pastured poultry processing methods has failed to yield a record of the data that is necessary to validate the safety of broilers processed by these methods. The objective of this study was to establish baseline data and compare the prevalence and concentrations of *Salmonella* and *Campylobacter* on pasture-raised broiler carcasses processed on-farm, at the small USDA-IF and at an MPU pilot plant.

2. Materials and methods

2.1. Study design and sampling scheme

Over a one year period, this study was conducted at independent, small-scale, pasture-raised broiler farms that processed birds at the site of production (on-farm), at a small USDA-IF or at an MPU pilot plant in the southeastern region of the United States. The participating farmers produced approximately 1000 broilers per year. Samples were collected during 12 on-farm visits in accordance with the farmers' broiler processing schedules. One producer raised and processed Cornish Cross breed broilers, while the other three producers used slower-growing breeds (i.e., Freedom Rangers and K-22). Ten sampling visits were conducted between two small USDA-IF and five processing runs were conducted at the MPU pilot plant. At each visit to the farms that processed birds on-farm, at the USDA-IF, and during each MPU processing run, 10 post-chill broiler carcasses were randomly selected and rinsed using the whole carcass rinse method (USDA, 2011a,b).

Birds were processed manually on the farm in an open-air setup or at a processing station in an enclosed shed. Processing stations included kill cones, a single-stage static scalder, a mechanical batch picker, stainless steel tables for evisceration, a water hose for spray washing carcasses, and large containers filled with ice water as a chill tank. A sharp knife was used to slaughter the birds at 9–10 weeks of age. Antimicrobial interventions for control of pathogens, cleaning and sanitizing practices varied from farm to farm. All of the farmers used ice water in the chill tank. Interventions included the use of vinegar or apple cider vinegar in the chill tank. Workers included family and friends of varying ages and levels of experience with processing broilers. In most cases, farm animals such as pigs, horses, goats, cows and herding dogs were also present on the farms.

The two small USDA-IF were located in rural areas of the southeastern United States. Both were equipped to process small batches (less than 500/day) of pasture-raised broilers from independent producers. Pasture-raised Red Rangers and Cornish Crosses were processed at these facilities. A batch processing system was used and most of the processing was performed manually by employees of the establishments. Antimicrobial interventions for pathogen control included treatment of carcasses with a citric and lactic-acid based antimicrobial spray. Carcasses were chilled in a chill tank filled with ice water. Visitors were required to use a sanitizing footbath upon entry to the facility and hairnets, aprons, and gloves were required during the sample collection process. Processed birds were inspected by a USDA-FSIS employee.

The University of Arkansas (UA) Poultry Science Department MPU pilot plant was located at the UA-Agriculture Experiment Station in Fayetteville, AR. Workers were trained poultry and food scientists, graduate students and pilot plant employees. Pasture-raised broilers were delivered to the facility by local farmers and were processed on the same day. Breeds included Ross 708, Cobb 700, Freedom Rangers and Naked Necks. The batch processing system consisted of a killing tunnel, 5 SHC-16 shackles, a 5A140 scalder with attached PDK Dunkmaster immersion unit, a JS-2A Spin-Pik picker and a chill tank. All MPU components were manufactured by the Pickwick Company (Cedar Rapids, IA). Birds were stunned and killed with a hand held electric stun knife and were allowed to bleed out for 2–5 min. After scalding and defeathering, evisceration was performed manually with scissors and gloved hands. No antimicrobial interventions were used during MPU processing. Carcasses were chilled in chill tanks filled with ice water.

2.2. Sample collection

Premeasured autoclaved water was added to sterile field bottles and was transported on ice to the sample collection site. Pasture-raised broiler carcasses were removed from the chill tank after 1 h of immersion chilling and excess water was drained from the cavity. Each carcass was placed into a sterile poultry rinse bag (Nasco; Fort Atkinson, WI) and 400 ml of sterile water was poured into the cavity. The carcass was rinsed for 1 min using a rotating arc motion as described in the USDA-FSIS method (USDA-FSIS, 2011a,b). The rinsate was aseptically drained from the rinse bag into a sterile field bottle (Nalgene, Rochester, NY) and was placed on ice for transport to the laboratory.

2.3. Analysis for Salmonella and Campylobacter

All samples were processed and assayed on the day of collection. The 3-tube Most Probable Number (MPN) method was used for quantification of *Salmonella* according to USDA-FSIS methods (USDA-FSIS, 2008a, 2011a). The detection limit for *Salmonella* in carcass rinse samples was a MPN of 12 salmonellae per carcass (95% CI: 6–38.4 MPN salmonellae/carcass). For each carcass rinse sample, nine tubes containing Buffered Peptone Water (BPW; Difco, Sparks, MD) (3 tubes each of 1 ml 10X BPW, 9 ml 1X BPW and 9 ml 1X BPW) were incubated with carcass rinsate in the amounts of 10 ml, 1 ml and 0.1 ml, respectively. Tubes were incubated at 37 °C for 24 h. After incubation, 0.5 ml and 0.1 ml of each BPW pre-enrichment tube was added to 10 ml of Tetrathionate broth (TT broth; Difco) and 10 ml of Rappaport-Vassiliadis (RV broth; Difco) respectively. Enrichment tubes were incubated for 24 h at 42 °C. Tubes were vortexed and a 10 μl loopful from each enrichment broth was streaked onto Brilliant Green Sulfa agar (BGS; Difco) and Xylose Lysine Tergitol-4 Agar (XLT4; Difco) plates and incubated for 24 h at 37 °C. Colonies typical of *Salmonella* were inoculated onto Triple Sugar Iron Agar (TSI; Difco) and Lysine Iron Agar (LIA; Difco) slants and were incubated at 37 °C for 24 h. All BGS and XLT4 plates were incubated for an additional 24 h and colonies presumed to be *Salmonella* were inoculated onto additional LIA and TSI slants and incubated as previously described. Slants were examined as sets for reactions typical of *Salmonella* and were further tested for agglutination using *Salmonella* O Poly A-I & Vi antiserum (Difco). Colonies with a presumptive positive reaction on LIA and TSI slants that did not agglutinate were further tested using real-time PCR

(Stratagene Mx 3005P, Santa Clara, CA). Total DNA was extracted from the isolates according to the method described in Anderson et al. (2010). Real-time PCR detection of *Salmonella* was performed as follows: reactions were conducted in a total volume of 25 μl. Each reaction included 12.5 μl of 2X Brilliant® SYBR® Green I qPCR Master Mix (Stratagene), 10.25 μl of nuclease free water (Qiagen), 0.125 μl of each primer (Forward: 5′-AACTTCATCG-CACCGTCA-3′; Reverse: 5′-TATTGTCACCGTGGTCCAG-3′[adapted from Bohaychuk, Gensler, McFall, King, and Renter (2007)] 135 nM final concentration); and 2 μl of *Salmonella* total DNA. The reaction conditions for amplification were 95 °C for 10 min, and 40 cycles of 95 °C for 15 s, 55 °C for 30 s, and 72 °C for 15 s. Colonies confirmed as *Salmonella* were preserved on Tryptic Soy Agar (TSA; Difco) and stored at 4 °C.

The direct plating and enrichment method was used for detection and enumeration of *Campylobacter* (USDA-FSIS, 2011b). The detection limit for direct plating was 400 CFU of *Campylobacter*/carcass. Serial dilutions of the rinsate were prepared in room temperature Phosphate Buffered Saline (PBS; Difco) and were spread plated on pre-made modified Campy-cefex agar plates (Hardy Diagnostics, Santa Maria, CA). For each sample, 250 μl of undiluted rinse was spread onto 4 plates and subsequent dilutions were achieved by plating 100 μl of the 10-fold dilution series on duplicate plates. Plates were placed in sealable plastic bags or in a rectangular jar system (7 L) (Mitsubishi Gas Chemical Company, Inc., Osaka, Japan) flushed with microaerobic gas (5% O_2, 10% CO_2, and 85% N_2) and were incubated at 35 °C for 48 h per the manufacturer's recommendation. Confirmation of presumptive positive colonies was based on cellular morphology and motility under a phase contrast microscope (Olympus BX40, Center Valley, PA) and a positive reaction in a latex agglutination immunoassay (Hardy Diagnostics). For each sample, the dilution that contained confirmed colonies within the countable range (15–300 CFU/plate) was used to calculate the CFU/ml of sample according to the method outlined in (USDA-FSIS, 2011b). For enrichment of each carcass rinse, 30 ml of the sample was added to 30 ml of Bolton Enrichment Broth (Hardy Diagnostics), and incubated for 48 h at 35 °C under microaerobic conditions. If direct plating of the sample did not display colonies typical of *Campylobacter*, the Bolton Broth enrichment cultures were plated on Campy-cefex agar and were confirmed as described earlier.

2.4. Data analysis

The outcomes of the study were the prevalence and concentrations of *Salmonella* and *Campylobacter* on pasture-raised broiler carcasses. The concentration data (MPN or CFU/ml) were adjusted to the original rinse volume (400 ml) and were $\log_{10}$ transformed to approximate normality. The prevalence data were cross-tabulated and compared by processing method (on-farm, USDA-IF, and MPU), followed by a comparison of breeds within each processing method using a Fisher's exact test or 2-by-n likelihood ratio chi-square test in STATA software version 10.1 (Stata Corp., College Station, TX).

The relationship between the pathogen prevalence on the carcasses and the pastured broiler processing method and breed (within each processing method) was assessed using a generalized linear model, with binomial error distribution, logit link function and adjustment for dependency within farms using generalized estimated equations (GEE) in STATA. For pathogen concentration data, the relationship between the $\log_{10}$ MPN or CFU/carcass and the broiler processing method and breed (within each processing method) was assessed using the GEE model, with identity link function to adjust for dependency within farms in STATA. A *P*-value less than 0.05 was considered significant.

3. Results and discussion

The current study established an initial record of quantified *Salmonella* and *Campylobacter* populations on pasture-raised broiler carcasses processed on-farm, at small USDA-IF, and in a MPU pilot plant. A total of 120, 100, and 50 carcass rinse samples were tested from small-scale pasture-raised broiler farms, the small USDA-IF, and the MPU pilot plant, respectively.

3.1. Salmonella on pasture-raised broiler carcasses

The *Salmonella* prevalence and mean log MPN concentration on chicken carcasses by processing method is shown in Table 1. The distribution of the mean log MPN concentrations of *Salmonella* in carcass rinses is shown in Fig. 1. The *Salmonella* prevalence and mean log MPN per carcass was significantly different ($P < 0.05$) between the processing methods. The prevalence of *Salmonella* in birds processed on-farm and the small USDA-IF in the current study is relatively greater than data reported in previous studies. Lestari, Han, Wang, and Ge (2009) reported 20.8% of national-brand organic broiler carcasses ($n = 53$) examined from 7 chain grocery stores in Louisiana were *Salmonella*-positive. Moreover, Cui, Ge, Zheng, and Meng (2005) revealed that 61% ($n = 198$) of organic broiler carcasses at retail were *Salmonella*-positive. In a study by Melendez et al. (2010), 50% ($n = 36$) of pasture-raised broiler carcasses purchased from a natural foods retail store or obtained from a local processing plant were *Salmonella*-positive.

Salmonella was not detected on carcasses processed by the MPU in the current study. This finding is in agreement with Killinger, Kannan, Bary, and Cogger (2010) which reported a zero prevalence of *Salmonella* in post-wash, pasture-raised carcasses used as untreated controls ($n = 60$) during MPU processing. Hoogenboom et al. (2008) reported that *Salmonella* was not detected in the feces of organically raised broilers at nine farms in the Netherlands. The occurrence of undetectable *Salmonella* may be due to farm management practices in addition to a seasonal effect on the pasture-raised broiler farms. In a six year study of raw retail broilers ($n = 1127$), Wilson (2002) reported a significant seasonal trend of increased *Salmonella* prevalence during the first quarter of each year. In the current study, sampling at the farms located on the eastern end of the southeast region of the United States occurred during all four seasons from the fall of 2011 through the summer of

Table 1
Salmonella prevalence and concentration on post-chill pasture-raised broiler carcasses (overall and by breed).

Breed	Prevalence	Mean log MPN	95% CI
On-farm			
Carcasses	89%^{A} ($n = 120$)	1.779^{A}	1.598–1.960
Cornish cross	^{a}86% ($n = 50$)	^{a}0.919	0.682–1.155
K-22	^{a}85% ($n = 20$)	^{a}1.983	1.660–2.307
Freedom Ranger	^{a}94% ($n = 50$)	^{a}1.716	1.551–1.886
USDA-IF			
Carcasses	43%^{B} ($n = 100$)	0.782^{B}	0.581–0.984
Cornish Cross	^{a}8.0% ($n = 50$)	^{a}0.089	0.004–0.175
Red Ranger	^{b}78% ($n = 50$)	^{b}1.475	1.192–1.759
MPU			
Carcasses	*0%^{C} ($n = 50$)	*0^{C}	0
Cobb 700	0% ($n = 20$)	0	0
Ross 708	0% ($n = 10$)	0	0
Freedom Ranger	0% ($n = 10$)	0	0
Naked Neck	0% ($n = 10$)	0	0

Values in the same column that are not followed by the same uppercase letter are significantly different ($P < 0.05$). Values in the same column (within a processing method) that are not preceded by the same lowercase letter are significantly different. **Salmonella* was not detectable via the USDA-FSIS (2008a). Most Probable Number protocol.

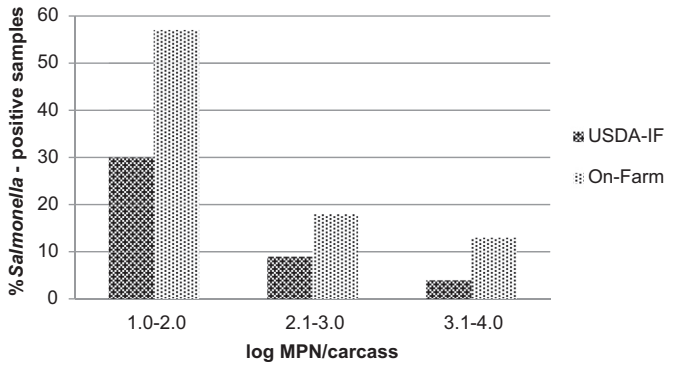

Fig. 1. Percentage bar chart illustrating the $\log_{10}$ Most Probable Number (MPN) of *Salmonella* on post-chill, pasture-raised broiler carcasses processed on-farm or in USDA-inspected facilities (USDA-IF). *Salmonella* was not detected on birds processed at the Mobile Processing Unit (MPU) pilot plant.

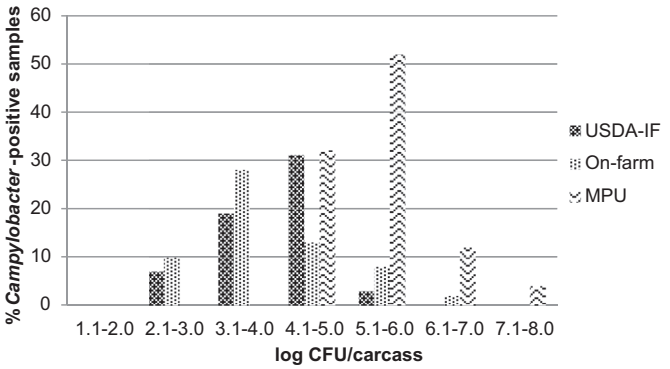

Fig. 2. Percentage bar chart illustrating *Campylobacter* $\log_{10}$ CFU on post-chill, pasture-raised broiler carcasses processed on-farm, in a Mobile Processing Unit (MPU) or in the small USDA-inspected facilities (USDA-IF).

2012. Sample collection for birds processed in the MPU occurred during the summer of 2012.

3.2. *Campylobacter* on pasture-raised broiler carcasses

The *Campylobacter* prevalence and concentration on pasture-raised broiler carcasses is shown in Table 2. The prevalence of *Campylobacter* on broiler carcasses was not significantly different ($P > 0.05$) by processing method. The distribution of the mean log CFU of *Campylobacter* on carcass rinses is shown in Fig. 2. Birds processed in the MPU had significantly higher ($P < 0.05$) *Campylobacter* concentrations than those processed on-farm and at the USDA-IF.

The prevalence of *Campylobacter* on carcasses processed by the MPU may also be due to seasonal effects on the pasture-raised broiler farms. In a one-year study of conventional retail market broilers, Willis and Murray (1997) reported that the highest recovery percentage of *Campylobacter* occurred during June and July of that year, and both months had a 96.7% ($n = 30$) *Campylobacter*-positive percentage. Furthermore, Stern et al. (2001) reported that the highest prevalence of *Campylobacter* in fecal samples of 32 broiler flocks was detected during the summer months. In the current study, sampling of all MPU-processed carcasses occurred during the summer months and 83% of on-farm processed carcasses were sampled during the summer months. Although *Salmonella* was not detected on carcasses processed by the MPU, *Campylobacter* concentrations were the higher on these carcasses compared to those processed by the other two methods in this study. It is possible that the birds processed by the MPU were not shedding *Salmonella* around the time of slaughter, but were shedding *Campylobacter*. In commercial broiler processing, the management practices used to control *Salmonella* often have little impact on *Campylobacter* in the in the same environment due to significant differences in the physiology and ecology of these organisms (Newell & Fearnley, 2003). This may be true for small scale broiler production environments.

The prevalence and concentrations of *Campylobacter* on pasture-raised carcasses may also be due to the flock effect (i.e., variation in *Campylobacter* presence and numbers by flock) suggested by Berrang and Dickens (2000) and Wempe, Genigeorgis, Farver, and Yusufu (1983) during their assessments of conventionally raised broilers. Heuer et al. (2001) detected *Campylobacter* in 100% ($n = 22$) of organic flocks taken from pre-slaughter cloacal swabs. The *Campylobacter* prevalence data for carcasses processed on-farm and at the USDA-IF shown in Table 2 are in agreement with data reported by Hanning et al. (2010). The authors reported 75% ($n = 48$) of pasture-raised retail carcasses were positive for *Campylobacter*. Griggs, Bender, and Jacob (2006) reported a 96% ($n = 299$) prevalence of *Campylobacter* in pre-chill, antibiotic free broilers raised in small-scale production systems.

As for the pasture-raised broiler breed, *Salmonella* prevalence and concentration was significantly higher ($P < 0.05$) in Red Rangers when compared to Cornish Crosses processed in the USDA-IF (Table 1). Breed did not have a significant effect on the prevalence and concentration of *Salmonella* on carcasses processed on-farm. As shown in Table 2, breed had a significant effect ($P < 0.05$) on the prevalence and concentration of *Campylobacter*; Cornish Cross broiler carcasses processed on-farm had a significantly ($P < 0.05$) lower *Campylobacter* prevalence than Freedom Ranger and K-22 carcasses. However, Freedom Ranger carcasses had significantly ($P < 0.05$) higher *Campylobacter* concentrations than the Cornish Crosses processed on-farm. For carcasses processed at the USDA-IF, Red Rangers had significantly ($P < 0.05$) lower *Campylobacter* concentrations than the Cornish Crosses processed by this method.

The breed pathogen data comparisons in this study should be interpreted with caution since different breeds were raised within each processing method and the participating broiler farms were located in disparate areas of the southeastern region of the United States. Additionally, inter-laboratory variability of the methods for pathogen detection and quantification may have contributed to the differences between breeds and processing methods in this study.

Table 2
Campylobacter prevalence and concentration on post-chill pasture-raised broiler carcasses (overall and by breed).

Breed	Prevalence	Mean log CFU	95% CI
On-farm			
Carcasses	$70\%^{A}$ ($n = 120$)	2.432^{A}	2.061–2.803
Cornish Cross	$^{a}40\%$ ($n = 50$)	$^{a}0.903$	1.230–2.575
K-22	$^{b}90\%$ ($n = 20$)	$^{a}1.692$	0.991–2.392
Freedom Ranger	$^{b}92\%$ ($n = 50$)	$^{b}3.258$	2.834–3.681
USDA-IF			
Carcasses	$82\%^{A}$ ($n = 100$)	2.441^{A}	2.031–2.849
Cornish Cross	$^{a}90\%$ ($n = 50$)	$^{a}3.887$	3.491–4.283
Red Ranger	$^{a}74\%$ ($n = 50$)	$^{b}0.992$	0.559–1.426
MPU			
Carcasses	$100\%^{A}$ ($n = 50$)	5.438^{B}	5.243–5.633
Cobb 700	100% ($n = 20$)	$^{a}5.604$	5.369–5.838
Ross 708	100% ($n = 10$)	$^{a}5.316$	4.680–5.952
Freedom Ranger	100% ($n = 10$)	$^{a}5.438$	5.015–5.860
Naked Neck	100% ($n = 10$)	$^{a}5.229$	4.817–5.641

Values in the same column that are not followed by the same uppercase letter are significantly different ($P < 0.05$). Values in the same column (within a processing method) that are not preceded by the same lowercase letter are significantly different.

The lack of regulatory guidance regarding controlled rearing and processing practices on-farm combined with an emphasis on minimal antimicrobial interventions may play a role in the prevalence and concentrations of *Salmonella* and *Campylobacter* on small-scale broiler farms observed in some studies. During on-farm processing, the use of single-stage, static scalders without replacing the scald water might increase the potential for cross contamination of carcasses. Hard scalding temperatures (approximately 58–63 °C) may not significantly reduce *Salmonella* contamination on carcasses (Slavik, Kim, & Walker, 1995). Feather picking in a batch picker is an abrasive process that may result in the transfer of bacteria between birds by the rubber projections. McCrea et al. (2006) reported that the prevalence of *Salmonella* in free-range broilers increased from 0% upon entering the feather picker to 52% after defeathering. Moreover, Wempe et al. (1983) reported a 94.4% prevalence of *Campylobacter* in commercial feather picker drip samples.

Since the evisceration process has been associated with increased levels of *Campylobacter* (Izat, Gardner, Denton, & Golan, 1988) and *Salmonella* (Morris & Wells, 1970; Sarlin et al., 1998), the practice of manual evisceration on a flat surface during on-farm processing instead of using shackles or a stand may present a potential route for cross contamination if the surface is not properly cleaned and sanitized between birds. Additionally, immersion chilling has been named as a potential site for cross-contamination since multiple carcasses share the same water bath (Morris & Wells, 1970; Sarlin, 1998). Commercial processing operations use chlorinated water with agitators to move carcasses through one or more chill tanks (Mead et al., 2010). Most of the participating small-scale processors used a single, static chill tank which may have resulted in cross-contamination of carcasses over a period of time due to an accumulation of bacteria. Fanatico (2003) has suggested that small-scale poultry producers use one chill tank to lower the body temperature for broilers for 15 min and follow this by a second chill tank for the remainder of the immersion chilling process.

The 2008 USDA-FSIS baseline survey of *Salmonella* and *Campylobacter* in commercially processed, post-chill broilers reported a *Salmonella* mean log concentration of 1.75 MPN/carcass (USDA-FSIS, 2008b), which appears to correspond with the mean log concentrations of *Salmonella* in birds processed on-farm (1.78 MPN/carcass) and at the USDA-IF (0.78 MPN/carcass) in our study. The mean log concentration of *Campylobacter* in the USDA-FSIS baseline study (3.56 CFU/carcass) is lower than the mean log CFU/carcass for birds processed in the MPU (5.44 CFU/carcass), yet higher than the *Campylobacter* concentrations for the USDA-IF (2.44 CFU/carcass) and on-farm processors (2.43 CFU/carcass). To the best of the our knowledge, data on the quantification of *Salmonella* and *Campylobacter* for broilers raised and processed in small-scale poultry production systems are not available for comparison.

The objective of this study was to establish initial baseline data on the food safety of small-scale pasture-raised broilers processed on-farm, in a MPU pilot plant and at small USDA-IF. As a result, we did not evaluate potential management risk factors which may have contributed to the differences in the prevalence and concentrations of the pathogens in birds processed on-farm and at the small USDA-IF compared to the MPU. Furthermore, information on the breeding flocks and practices of the hatcheries associated with the participating pasture-raised broiler farms was not available.

4. Conclusions

The prevalence of pathogens on pasture-raised broiler carcasses may be the result of the *Salmonella* and *Campylobacter* dissemination on small pasture-raised broiler farms, which may impact the food safety of the products. Based on the results of this baseline study, most pasture-raised broilers processed by the three methods were contaminated with *Salmonella* and/or *Campylobacter* with the exception of the carcasses processed in the MPU pilot plant where *Salmonella* was not detected on carcasses. The prevalence and concentration of *Campylobacter* contamination were higher and lower for birds processed in the MPU and on-farm, respectively. Carcasses processed on-farm were mostly positive for *Salmonella* with levels that correspond with the USDA-FSIS nationwide microbiological baseline data collection program for young chickens (USDA-FSIS, 2008b). The current work provides insight into small-scale poultry production practices and provides a record of data which may serve as a guide for future improvement of these practices. Further research is needed regarding the small-scale broiler production environment in relation to available processing methods, on-farm practices and pathogen levels, the breed of bird, and potential intervention methods.

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