Effect of kosher salt application on microbial profiles of poultry carcasses

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ABSTRACT The effect of conventionally applied kosher salt on the microbiological profile of posteviscerated chicken carcasses obtained from a local commercial processing facility was evaluated. The broiler carcasses were divided into treatments 1 through 8. Standard sampling methods were used to evaluate *Salmonella* prevalence, aerobic plate counts, coliforms, generic *Escherichia coli*, and psychrotroph counts. Results indicate significant reductions in microbial populations in all the salted groups compared with controls. Significant reductions (1.45, 2.31, 2.81, and 1.48 log cfu/mL of rinse) were obtained for aerobic plate count (APC), coliforms, generic *E. coli*, and psychrotroph counts, respectively, on prechill salt-treated carcasses compared with controls. Salt-treated carcasses sampled after chilling had lower microbial populations compared with control chilled samples with significant reductions in coliforms and generic *E. coli* (1.25 and 1.77 log, respectively). Salt-treated samples had lower counts on APC and psychrotrophs after 10 d of refrigerated storage compared with controls. Finally, drip loss of salt-treated carcasses was lower after 24 h compared with nontreated controls. Based on the results, it can be concluded that salting process is an effective contributor to microbial reductions during processing that needs further investigation as a possible intervention in commercial poultry processing settings.

Key words: kosher salt, aerobic count, *Escherichia coli*, psychrotroph, broiler carcass

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INTRODUCTION

Poultry carcasses on a conventional processing line can be contaminated with a variety of microorganisms, including pathogenic bacteria such as *Salmonella* spp. and *Campylobacter jejuni* (Lillard, 1990; Clouser et al., 1995) as well as spoilage microorganisms. Several studies have been conducted to evaluate the efficacy of chemical and nonchemical interventions to reduce microbial contamination in poultry (Bauermeister et al., 2008; Isohanni et al., 2010; Vaz et al., 2010). The majority of the studies have been conducted with chemicals, especially with chlorine and its derivatives; however, trade restrictions in certain markets, demonstrated minimal efficacy, and potential production of harmful residues such as trihalomethanes (Northcutt and Lacy, 2000; Northcutt and Jones, 2004) have stimulated further research on processing interventions that would minimize chlorine use. Commercial efforts continue to find suitable alternatives that are more efficient and cost-effective compared with existing intervention strategies.

Salt has been used by the food industry as a preservative ingredient. An alternative use of salt in poultry processing is the salting of carcasses during processing of kosher products. Kosher salt does not dissolve readily when applied to broiler carcasses during the koshering process. The kosher name is attributed because of its use in making meats kosher: by extracting the blood and other pigments from the meat (Regenstein and Regenstein, 1988). Because of its larger grain size compared with regular table salt, this product does not dissolve readily when meats are coated. The salt tends to remain on the surface of meat for longer time periods, thus allowing fluids to leach out of the meat (Hutchinson, 2007). The koshering operation is accomplished by immersing the bird in cold water (8 to 12°C) for 30 min, a process called Shriah, to remove coagulated blood (Oscar, 2008). The carcasses are salted intensively all over the surface and left for 1 h at room temperature for blood to drip out. Finally, the carcasses

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are rinsed with cold water, a process called Hadacha (Regenstein and Regenstein, 1988). The probability of microbial contamination is higher in kosher-slaughtered poultry compared with nonkosher products because of additional handling required when processing kosher poultry products. Critical areas that affect the microbial quality of the end product include the temperature of the water that is used for rinsing and application of salt (Regenstein and Regenstein, 1988). However, it seems that kosher salting of carcasses provides for a natural intervention that includes employee safety, spray cabinets, and cost-related issues due to the use of chemicals.

The 2 immersions in water in the koshering operation are other potential sites for bacterial cross-contamination. Although known, current available literature does not completely elucidate the antimicrobial efficacy of kosher salt when applied to broiler carcasses during kosher processing. Hence, this study was aimed at evaluating the antimicrobial effects of the dry application of kosher salt on microbial profiles of eviscerated chicken carcasses obtained from a commercial processing facility. The effect of the salt application on the shelf life of the product and some quality parameters was also determined.

MATERIALS AND METHODS

Sample Collection and Treatment Combinations

Posteviscerated chicken carcasses were obtained from a local commercial processing facility. Carcasses were placed individually in bags and transported in a cooler to the Poultry Science Research Center at Texas A&M University immediately for treatment application and microbial analysis. Carcasses were divided into the following treatment groups: 1) control, carcasses were chilled to a temperature of 12°C and sampled; 2) prechilled + salt, carcasses were chilled to a temperature of 12°C and subsequently treated with salt and sampled; 3) control postchilled, carcasses were treated like group 1, chilled to a temperature of 4°C, and then sampled; 4) prechilled + salt + postchilled, carcasses were chilled to a temperature of 12°C followed by salt treatment and subsequent chilled to a temperature of 4°C and then sampled; 5) postchilled + salt, carcasses chilled to a temperature of 4°C and subsequently treated with salt, rinsed to remove the salt, and sampled; 6) control prechilled and stored, carcasses were treated like group 1, stored for 10 d at 4°C, then sampled; 7) prechilled salted postchilled and stored, carcasses were treated like group 4, stored for 10 d at 4°C, then sampled; and 8) postchilled salted and stored, carcasses were treated like group 5, stored for 10 d at 4°C, then sampled. A diagram describing the treatment combination for this experiment conducted on d 0 and 10 of storage is shown on Figure 1. Chicken carcasses obtained from groups 6, 7, and 8 were used to determine Commission Internationale d'Eclairage (**CIE**) L*, a*, and b* color values and drip loss on d 10 of storage only.

Carcasses belonging to treatment groups 2, 4, 5, 7, and 8 were subjected to the salting treatment with Kosher salt (Morton Food Service Coarse Kosher Salt, Chicago, IL) either before chilling (groups 2, 4, and 7) or after chilling to 4°C (groups 5 and 8). Individual carcasses were manually rubbed with 1 kg of kosher salt on both internal and external sides for approximately 1 min under controlled conditions using separate rubber gloves for each treated carcass. The rubber gloves were changed while working with carcasses in different treatment groups. Treated carcasses were then left at room temperature for approximately 1 h. At the end of 1 h, individual carcasses were rinsed with 2 L of water at room temperature. Carcasses belonging to groups 4 and 7 were further chilled to a temperature of 4°C after the salt treatment. All the carcasses were subsequently placed in individual bags for microbiological analysis. Carcasses in groups 5 and 8 were treated with the salt after chilling the carcasses to 4°C, kept for 30 min, then washed with water and sampled.

Sampling and Microbiological Analysis

Microbial analysis for aerobic plate count (**APC**), coliforms, generic *Escherichia coli*, *Salmonella*, and total psychrotrophs on broiler carcasses were performed, and the whole carcass rinse method was employed. A total of 120 chicken carcasses (8 per treatment) was placed individually in plastic bags and rinsed with approximately 100 mL of sterile buffered peptone water (**BPW**, Difco, Detroit, MI) for approximately 1 min. The rinse solution was collected in aseptic bottles for further analysis. Standard sampling methods were used to evaluate APC, coliform, generic *E. coli*, psychrotrophs, and *Salmonella* prevalence. For aerobic counts, decimal dilutions of the rinse solution were spread plated on plate count agar (Difco). Plates were subsequently incubated at 37°C for 48 h.

To enumerate coliforms and generic *E. coli*, rinses were serially diluted and approximately 1 mL of each dilution was dispensed onto 3M Petrifilm (*E. coli*/coliforms) count plates (3M Inc., St. Paul, MN). Petrifilm plates were incubated at 37°C for 24 h for total coliforms (red colonies with gas production) and then reincubated for additional 24 h for generic *E. coli* (blue colonies with gas production). Psychrotrophic enumeration was done by plating decimal dilutions on tryptic soy agar (Difco) with subsequent incubation at 7°C for 7 d.

For determining *Salmonella* prevalence, whole carcass rinses were preenriched in BPW (approximately 25 mL of the rinse solution was transferred to 25 mL of sterile BPW) and incubated for 24 h at 37°C. Preenriched samples were then selectively enriched in Rappaport Vassidialis (Difco) by transferring 0.1 mL of BPW to 9 mL of Rappaport Vassidialis followed by incubation for 24 h at 41°C. Selective plating was done on Xylose

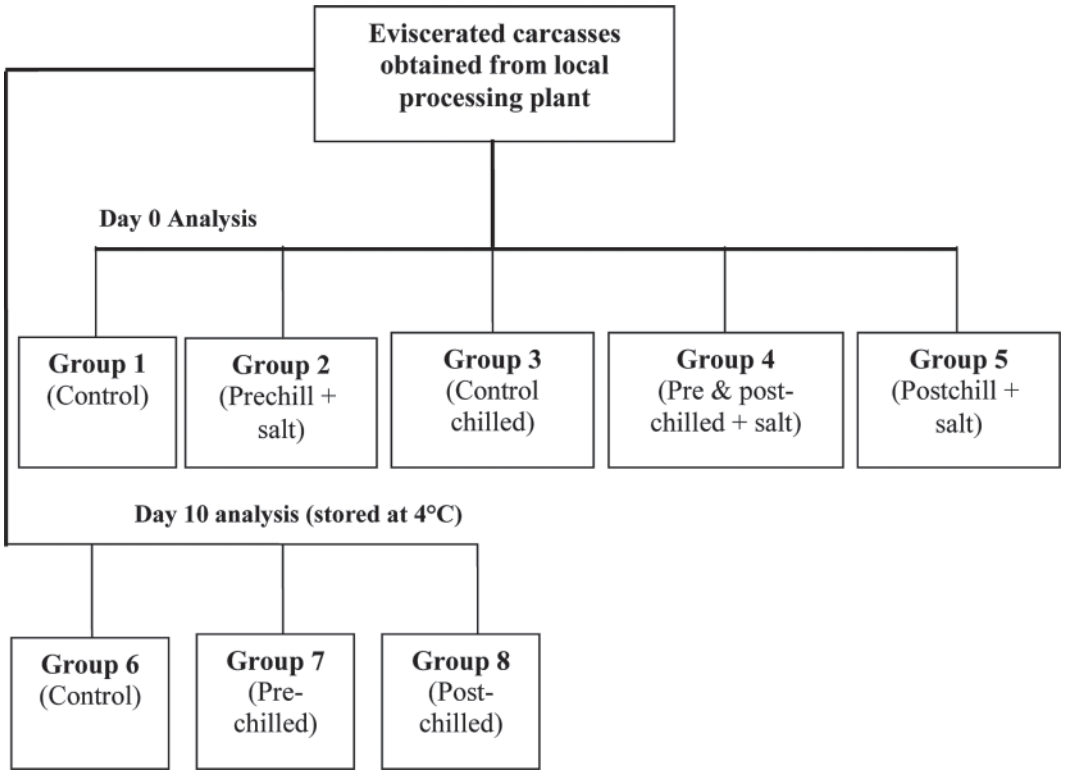

Figure 1. Treatment combinations for microbial profile analysis.

Lysine Tergitol agar (Difco) with incubation at 37°C for 24 to 48 h. Suspected colonies (black) were confirmed serologically using the polyvalent A through I serum for agglutination.

Drip Loss and Color Evaluations

A total of 45 samples, 15 for each group (5 per treatment), were used for drip loss analysis and color measurements (CIE L* = lightness, a* = redness, and b* = yellowness). Carcasses were subjected to the treatments described in group 3, 4, and 5; that is control chilled, prechilled salted and postchilled, and postchill salted and individually weighed. Carcasses were then stored in a refrigerated room at 4°C in trays to allow for dripping, and reweighed after 24 h to determine drip loss. Drip loss was calculated as (weight of drip loss/initial weight of fillet) × 100.

For CIE L* (lightness), a* (redness), and b* (yellowness) color determination, chicken carcasses were measured using a Minolta colorimeter (Minolta Chroma Meter CR-300, Minolta Co. Ltd., Ramsey, NJ), immediately after kosher salt interventions. Before conducting each measurement, the colorimeter was calibrated each time with a white reference tile (Y = 88.5, x = 0.310 and y = 0.317) and 3 different readings per sample were obtained.

Statistical Analysis

Count data obtained was transformed logarithmically and reported as $\log_{10}$ cfu/mL of carcass rinse. Each experiment was independently replicated 3 times, and 5 replicates were sampled per treatment. All count, color, and drip loss data were analyzed by one-way ANOVA using the SAS statistical analysis software program (1998), version 9.1 (SAS Institute Inc., Cary, NC). Where significant differences were observed ($P < 0.05$), separation of means was accomplished using LSMEANS.

RESULTS

Results indicate significant reductions in total microbial populations for all the groups compared with eviscerated controls, group 1 ($P < 0.05$; Table 1). The initial microbial load on the broiler carcasses (controls) was approximately 4.82 log cfu/mL. Significant reduction in the populations was observed in both control chilled and salt-treated samples ($P < 0.05$), and a reduction of approximately 1.05 ~1.45 log cfu/mL was obtained when compared with control group. However, no significant difference was observed between pre- and postchilled treatment groups ($P > 0.05$).

Significant reduction in coliforms was observed in carcasses chilled to a temperature of 4°C on d 0, and a reduction of 1.48 log cfu/mL (group 3) was obtained when compared with control samples ($P < 0.05$). Another reduction of approximately 0.6 or 0.8 log cfu/mL based on group 3, was obtained for carcasses belonging to groups 2 and 4. A further reduction (1.25 log cfu/mL) was obtained in samples that were postchilled when compared with control chilled samples. However, there was no significant difference in coliform populations between samples belonging to groups 2, 3, 4, and 5 ($P > 0.05$).

Table 1. Microbial profiles[1] on broiler carcasses on d 0[2]

Item (log_{10} cfu/mL of rinse)	Prechilled samples		Chilled samples		Postchilled salt
	Group 1	Group 2	Group 3	Group 4	Group 5
Aerobic plate count	4.82 ± 0.11^{a}	3.37 ± 0.21^{b}	3.77 ± 0.24^{b}	3.68 ± 0.31^{b}	3.42 ± 0.30^{b}
Coliforms	3.71 ± 0.15^{a}	1.40 ± 0.54^{b}	2.23 ± 0.21^{b}	1.57 ± 0.18^{b}	0.98 ± 0.67^{b}
Generic *Escherichia coli*	3.18 ± 0.15^{a}	0.37 ± 0.08^{d}	2.27 ± 0.16^{b}	0.88 ± 0.09^{c}	0.50 ± 0.18^{cd}
Psychrotrophs	2.12 ± 0.28^{a}	0.64 ± 0.32^{b}	0.96 ± 0.26^{b}	0.73 ± 0.38^{b}	0.57 ± 0.29^{b}

[a–d]Means within the row followed by different letters are significantly different ($P < 0.05$).

[1]Each data entry represents the mean ± SE.

[2]Group 1: controls (carcasses that did not receive any salt treatment); group 2: prechilled + salt (carcasses were chilled to a temperature of 12°C and subsequently treated with salt and sampled); group 3: control chilled (carcasses were chilled to a temperature of 4°C and sampled); group 4: prechilled + salt + postchilled (carcasses were chilled to a temperature of 12°C followed by salt treatment and subsequent chilling to a temperature of 4°C and then sampled); group 5: postchilled + salt (carcasses chilled to a temperature of 4°C and subsequently treated with salt, rinsed to removed the salt, and sampled), n = 8.

Chilling of carcasses to a temperature of 4°C significantly reduced (0.91 log cfu/mL) *E. coli* populations on broiler carcasses when compared with controls ($P < 0.05$). A further significant reduction by 1.4 log cfu/mL was obtained for carcasses that were treated with salt and subsequently chilled down to a temperature of 4°C ($P < 0.05$). Significant reductions of approximately 1.9 and 1.8 log cfu/mL was observed for carcasses from groups 2 and 4, respectively when compared with control chilled samples ($P < 0.05$). However, no significant difference in log populations was obtained between carcasses from groups 2 and 5, and 4 and 5, respectively ($P > 0.05$).

The initial load of psychrotrophs on processed broilers was low compared with control microbial groups, and significant reduction (1.16 ~ 1.55 log cfu/mL) in population was obtained when carcasses were chilled to a temperature of 4°C ($P < 0.05$). No further significant reductions in populations were obtained for other treatment groups ($P > 0.05$).

Broiler carcasses obtained from the processing plant were subjected to salt treatment and stored in refrigerator at a temperature of 4°C for 10 d for shelf-life evaluation (Table 2). It was observed that prechilled and salt-treated carcasses had significant reductions (0.82 and 1.11 log cfu/mL) in APC and psychrotrophs, respectively, compared with control samples ($P < 0.05$). All the samples including controls tested negative for *Salmonella*.

In addition, drip loss on postchilled and kosher-treated samples was 53.8% less than nontreated counterparts, and it was significant ($P < 0.05$; Table 3). However, kosher salt application caused a decrease in lightness (CIE L*) and yellowness (CIE b*) on treated carcasses compared with controls, and redness (CIE a*) was not significantly influenced ($P > 0.05$).

DISCUSSION

The efficacy of kosher salt as an antimicrobial has been established based on the results obtained (Tables 1 and 2). Kosher salt as a natural intervention offers several advantages compared with other chemicals such as chlorine and chlorine-related compounds, organic acids, and quaternary ammonium compounds. Previous studies with chemicals such as 1% trisodium phosphate and 1% lactic acid produced reductions in psychrotrophs (Hwang and Beuchat, 1995; Hinton et al., 2007); however, the counts reported compared with the current study were higher. Also, studies that applied chlorine, acidified sodium chlorite, and ozone demonstrated significant reductions in generic *E. coli* (James et al., 1992; Graham, 1997; Kim et al., 1999; Kemp et al., 2001). Ozone in particular has been reported as being very effective against *E. coli* (Staehelin and Hoigne, 1985). Results when compared with the current study were found to be comparable, and a 0.8-log reduction of coliforms was reported for broiler carcasses treated with chlorine dioxide, which is significantly lower than what was obtained in the current study (2.73 log cfu/mL, group 5; Thiessen et al., 1984).

Table 2. Microbial profile[1] on broiler carcasses on d 10[2]

Item (log_{10} cfu/mL)	Group 6	Group 7	Group 8
Aerobic plate count	6.30 ± 0.21^{a}	5.48 ± 0.30^{b}	6.07 ± 0.13^{a}
Psychrotrophs	7.00 ± 0.14^{a}	5.89 ± 0.30^{b}	6.79 ± 0.15^{a}
Salmonella	—[3]	—	—

[a,b]Means followed by different letters within the row are significantly different ($P < 0.05$).

[1]Each data entry represents the mean ± SE.

[2]Group 6: control chilled and stored (carcasses chilled to 4°C and stored for 10 d at 4°C then sampled); group 7: prechilled salted, postchilled and stored (carcasses were chilled to a temperature of 12°C and subsequently treated with salt and subsequent chilling to 4°C and then sampled); group 8: postchilled salted and stored (carcasses were chilled to a temperature of 4°C, stored for 10 d at 4°C, and sampled), n = 8.

[3]*Salmonella* was not detected.

Table 3. Commission Internationale d'Eclairage L*, a*, and b* color and drip loss[1] of chicken carcasses after kosher salt interventions

		Color		
Treatment[2]	Drip loss	Whiteness	Redness	Yellowness
Group 6	5.27 ± 0.69[a]	74.11 ± 0.30[a]	2.32 ± 0.40	5.43 ± 0.75[a]
Group 7	4.42 ± 0.46[b]	70.95 ± 1.05[b]	2.14 ± 0.39	1.13 ± 1.20[b]
Group 8	2.43 ± 0.39[c]	70.89 ± 0.54[b]	2.19 ± 0.48	1.92 ± 0.89[b]

[a–c]Means followed by different letters within the column are significantly different ($P < 0.05$).

[1]Each data entry represents the mean ± SE; n = 5.

[2]Group 6: control chilled and stored (carcasses were chilled to 4°C and stored for 10 d at 4°C, then sampled); group 7: prechilled salted postchilled and stored (carcasses were treated like group 4, stored for 10 d at 4°C then sampled); group 8: postchilled and stored (carcasses were treated like group 5, stored for 10 d at 4°C, then sampled).

Antimicrobial efficacies of chlorine and chlorine dioxide on *Salmonella* were previously analyzed by several authors (Wabeck et al., 1968; Lillard, 1979; Lee-Shin et al., 1992). Although significant reductions were reported, the results were more often mixed. The current study did not reveal any prevalence of pathogens for the controls and the salt-treated samples; hence, the effect of salt on pathogens cannot be confirmed at this time. Whereas chlorine and chlorine-related compounds are oxidizing agents primarily affecting the cell membrane permeability, the principal mode of action of salt is osmosis (Mager et al., 1956). Several investigators reported shrinkage of cell walls in salt solutions by gram-negative bacteria (Avi-Dor et al., 1956; Marquis, 1967). Current literature elucidating the mechanism of action of salt in vivo is limited and previous in vitro research reported that gram-negative bacteria are affected by the tonicity of the culture medium (Mager et al., 1956). The study demonstrated that turbidity of the bacterial suspension varied with changes in osmotic pressure of the suspending medium, and this phenomenon is reflected as optical effect. It was also suggested that the behavior of the microorganisms varied considerably when the composition of the culture medium was changed and this is attributed primarily to differential response of the bacteria to the changed osmotic pressure. The osmotic effect was suggested to be due to changes in the permeability of the cytoplasmic membrane that is primarily determined by the tonicity of the suspending medium (Mager et al., 1956).

In summary, it can be concluded that kosher salt is an effective antimicrobial that needs further investigation with regard to its application in a commercial poultry processing setup. The effect of salt on pathogens such as *Salmonella* (in vivo) needs further investigation to understand the complicated response of the bacterial cells. Although salt does offer a feasible alternative to chemical interventions, issues such as recycling and environmental pollution are challenges that need to be addressed.

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