Food Control 77 (2017) 199–209

Contents lists available at ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

Trisodium phosphate dip, hot water dip, and combination dip with/without brushing on broiler carcass decontamination

P. Singh [a], H.C. Lee [b], M.F. Silva [a], K.B. Chin [c], I. Kang [b,*]

[a] Department of Food Science & Human Nutrition, Michigan State University, East Lansing, MI 48824, USA
[b] Department of Animal Science, California Polytechnic State University, San Luis Obispo, CA 93407, USA
[c] Department of Animal Science, Chonnam National University, 77 Yongbong-ro, Buk-gu, Gwangju 500-757, Republic of Korea

ARTICLE INFO

Article history:
Received 17 October 2016
Received in revised form
29 December 2016
Accepted 10 February 2017
Available online 14 February 2017

Keywords:
Bacterial decontamination of broiler
Salmonella
Trisodium phosphate dip
Hot water dip
Brushing
Broiler skin structure

ABSTRACT

The purpose of this research was to evaluate the effects of trisodium phosphate dip (TSP), hot water dip (HWD) and their combination dip with/without brushing on broiler breast skin for bacterial reduction and structural changes. Eviscerated broiler carcasses were obtained from a local slaughter plant and immediately subjected to one of six treatments: 1) two tap water dips at 25 °C (TWD/TWD), 2) TWD/TWD with brushing (TWD/TWD/B), 3) TWD and TSP at 8%/25 °C (TWD/TSP), 4) TWD and HWD at 71 °C (TWD/HWD), 5) TSP and HWD (TSP/HWD), and 6) TSP/HWD with brushing (TSP/HWD/B). Each dip was conducted for 45 s with or without brushing at 5 s on/off during the second dip. Compared to the control (TWD/TWD), TSP/HWD significantly reduced mesophilic aerobic bacteria (MAB), *Escherichia coli* (*E. coli*), and total coliforms by 1.1, 0.9 and 1.0 log CFU/g, respectively, and *Salmonella* prevalence by 53.3% ($P < 0.05$), whereas TWD/TSP and TWD/HWD showed intermediate reductions ($P < 0.05$). Upon brushing, TSP/HWD/B reduced populations of MAB, *E. coli*, and total coliforms, and the prevalence of *Salmonella* more effectively than control of brushing (TWD/TWD/B) ($P < 0.05$). When two sampling methods were compared, the method of stomaching released fewer MAB and total coliforms (named loosely-associated cells) than the grinding of the stomached skin (named tightly-associated cells). Compared to controls (TWD/TWD and TWD/TWD/B), both TSP/HWD and TSP/HWD/B generally resulted in darker, less reddish, and more yellowish breast skin. Scanning electron microscope and histological images indicated that both TSP/HWD and TSP/HWD/B had deeper skin penetration than controls or TWD/HWD and TWD/TSP. Overall, TSP/HWD/B showed the most effectiveness in broiler carcass decontamination.

1. Introduction

Broiler chicken is the most favorite meat in the United States (U.S.) and many other countries. According to OECD/FAO (2014), poultry is expected to become the world's most consumed meat over the next 5 years. Poultry meat, however, is a leading cause of foodborne illnesses, particularly salmonellosis and campylobacteriosis, in the U.S. and the European Union (Centers for Disease Control and Prevention (CDC), 2012; Chaine, Arnaud, Kondjoyan, Collignan, & Sarter, 2013; European Food Safety Authority [EFSA], 2008; Hoffmann, Fischbeck, Krupnick, & McWilliams, 2007). Most poultry-related illnesses could be results from ineffective pathogen control strategies and inaccurate pathogen detection methods that are currently being used at farms and/or at processing plants (Interagency Food Safety Analytics Collaboration, 2015; Singh, Silva, Ryser, Ha, & Kang, 2016).

Over the last two decades, the broiler industry has adopted various intervention strategies against pathogens, which include the use of chlorine, organic acids, cetylpyridinium chloride (CPC), trisodium phosphate (TSP), etc. (Lillard, 1990; Li, Slavik, Walker, & Xiong, 1997; Sakhare, Sachindra, Yashoda, & Rao, 1999; Whyte, Collins, McGill, Monahan, & O'Mahony, 2001; Zhang, Jeong, Janardhanan, Ryser & Kang, 2011). While these strategies have been partly successful, many chemicals such as chlorine and CPC are not generally recognized as safe (GRAS), and others such as organic acids have negative organoleptic effects (Ricke, Kundinger, Miller, & Keeton, 2005).

Hot water sprays or dips have been shown to reduce bacterial load on broiler carcasses with their effectiveness dependent on water temperature and exposure time (Cox, Mercuri, Thomson, &

* Corresponding author.
E-mail address: ikang01@calpoly.edu (I. Kang).

http://dx.doi.org/10.1016/j.foodcont.2017.02.015
0956-7135/

Abbreviations

TWD/TWD Tap water dipping (TWD) (25 °C, 45 s) followed by second TWD (25 °C, 45 s)
TWD/TWD/B TWD (25 °C, 45 s) followed by second TWD (25 °C, 45 s) with intermittent manual brushing (5 s on/5 s off)
TWD/TSPTWD (25 °C, 45 s) followed by Trisodium phosphate (TSP) dipping (8%, 25 °C, 45 s)
TWD/HWD TWD (25 °C, 45 s) followed by hot water dipping (HWD) (71 °C, 45 s)
TSP/HWD TSP dipping (8%, 25 °C, 45 s) followed by HWD (71 °C, 45 s)
TSP/HWD/B TSP dipping (25 °C, 45 s) followed by HWD (71 °C, 45 s) with intermittent manual brushing (5 s on/5 s off)

Gregory, 1974; Purnell, Mattick, & Humphrey, 2004). In our previous study, hot water spraying (71 °C, 1 min) reduced total bacteria counts and the incidence of *Salmonella* on broiler carcasses but caused a partially cooked appearance (Zhang, Singh, Lee, & Kang, 2013).

On-line brushing with a water spray has been primarily used to remove fecal materials from broiler carcass surfaces before scalding. Berrang and Bailey (2009) assessed on-line washing with/without brushing of broiler carcasses between bleed-out and chilling steps in a commercial processing plant. Overall, their multiple-sequential washing decreased *Campylobacter* and *E. coli* populations as well as *Salmonella* prevalence, although none of single steps caused a significant difference.

Trisodium phosphate received GRAS status and was approved for use in broiler processing in 1992 (Capita, Alonso-Calleja, Garcia-Fernandez, & Moreno, 2002b). If used properly under optimum conditions, it can cause up to 79% reduction in *Salmonella* prevalence and 2 log reduction in *E. coli* population on chicken carcasses (Capita et al., 2002b).

In processing plants, most bird-to-bird contamination occurs during de-feathering and evisceration (Allen, Tinker, Hinton, & Wathes, 2003; Guerin et al., 2010; Rasschaert et al., 2008; Sarlin et al., 1998). Bacteria that are loosely associated with carcasses are likely to contribute to cross-contamination during processing, while tightly associated ones are likely to survive during chemical and physical antimicrobial exposure. Therefore, an intervention that is effective against loosely and tightly associated bacteria can reduce both cross contamination during processing and subsequent growth thereafter. During antimicrobial application, physical brushing is expected to expose hidden bacteria in crevices and ridges to chemical or physical treatments. Our recent study indicated that 10 swabbings and 10 stomachings recovered only 17 and 45% of mesophilic aerobic bacteria from broiler skin, respectively, whereas the remaining bacteria were recovered after grinding the swabbed or stomached skin (Singh, Lee, Chin, Ha, & Kang, 2015). Previously, several studies also used grinding or blending of broiler skin to recover tightly associated bacteria (Lee, Park, Kang, & Ha, 2014; Tamblyn, Conner, & Bilgili, 1997; Zhang et al., 2013).

Many studies have shown that a single treatment was less effective than a combination of physical and chemical treatments such as TSP with electricity, sodium carbonate with hot water, sodium carbonate with electricity, lactic acid with steam, and sodium hypochlorite with acidic electrolyzed water (Lecompte, Kondjoyan, Sarter, Portanguen, & Collignan, 2008; Li et al., 1994; Northcutt, Smith, Ingram, Jr, Hinton, & Musgrove, 2007; Rodriguez de Ledesma, Riemann, & Farver, 1996). Until now, no research has been conducted to evaluate the single and combined effects of three treatments (TSP, hot water dip - HWD, and brushing -B) against naturally occurring bacteria on broiler carcasses. Therefore, the objective of this study was to assess the effects of TSP, HWD, and their combination with and without brushing on broiler carcasses for the reduction of bacteria after stomaching (namely loosely-associated bacteria) and after subsequent grinding of the stomached skin (namely tightly-associated bacteria) as well as structural changes on the broiler skin, using scanning electron microscopy and histological staining.

2. Materials and methods

2.1. Broiler carcasses

A total of nine visits were made to a local broiler processing plant on nine different days over three months (three visits/month) to assess the effects of chemical and/or physical treatments on microbiological quality and structural changes of broiler carcass skin (~46-day-old, HubgbardM99/ross 708), using microbiological analysis and visual imaging (scanning electron microscope and histological staining), respectively.

2.2. Experiment I: control (TWD/TWD), trisodium phosphate dip (TWD/TSP), hot water dip (TWD/HWD), and combination of TSP and HWD (TSP/HWD)

In each of first three visits, 20 broiler carcasses were randomly selected from an industrial broiler processing line after evisceration. The carcasses were immediately subjected to one of four treatments (5 carcasses/treatment) as follows: 1) Control of tap water dipping (TWD) at 25 °C for two times - TWD/TWD, 2) TWD followed by 8% (wt/vol) trisodium phosphate dipping at 25 °C - TWD/TSP, 3) TWD followed by hot water dipping at 71 °C – TWD/HWD, and 4) 8% trisodium phosphate dipping at 25 °C followed by hot water dipping at 71 °C - TSP/HWD. Each dip was conducted for 45 s.

2.3. Experiment II: control (TWD/TWD), control with brushing (TWD/TWD/B), combination of TSP and HWD (TSP/HWD), and combination with brushing (TSP/HWD/B)

During each of second three visits, 20 broiler carcasses were similarly selected as before and subjected to one of four treatments (5 carcasses/treatment) as follows: 1) Control of tap water dipping (TWD) at 25 °C for two times - TWD/TWD, 2) TWD at 25 °C followed by a second TWD with brushing - TWD/TWD/B, 3) 8% trisodium phosphate dipping at 25 °C followed by hot water dipping at 71 °C - TSP/HWD, and 4) 8% trisodium phosphate dipping at 25 °C followed by hot water dipping at 71 °C with brushing - TSP/HWD/B. For carcass dipping, 18-L stainless steel buckets were filled up to ¾ of the capacity. A new bucket with fresh solution was used for every 5 birds that were dipped individually. Each dip was conducted for 45 s with/without brushing (5 s on/off) on carcass breast and neck area. For brushing, polyester brushes (Sparta® Spectrum® All Purpose Utility Scrub Brushes), having a bristle density of 38/cm^2, bristle diameter of 1 mm, and bristle length of 4.5 cm, were used after purchasing from Carlisle Foodservice Products (Batavia, IL).

2.4. Skin sample preparation methods in experiment I and II

After each treatment, 25 g of skin was aseptically taken from the breast and neck areas, placed in sterile WhirlPak bag (Nasco,