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Combination of a novel designed spray cabinet and electrolyzed water to reduce microorganisms on chicken carcasses

Huhu Wang [a,*], Jun Qi [b], Debao Duan [b], Yang Dong [a], Xinglian Xu [a], Guangzhou Zhou [b]

[a] National Center of Meat Quality and Safety Control, Nanjing Agricultural University, Nanjing 210095, PR China
[b] Jiangsu Collaborative Innovation Center of Meat Production and Processing, Quality and Safety Control, Nanjing Agricultural University, Nanjing 210095, PR China

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ABSTRACT

Minimizing microbial contamination on poultry carcasses during processing in slaughterhouses is imperative for delaying spoilage and extending the shelf-life of meat. In the present study, a novel spray cabinet was designed, and the reduction of microorganisms on chicken carcasses achieved by the application of this cabinet combined with electrolyzed water was assessed at a slaughter-line. The spray cabinet, precisely designed to be a U-shaped cabinet according to the transmission of chicken carcasses in plants, primarily consists of side-, down- and up-spray units with 0.3 MPa of pressure for each nozzle, with a total of 188 nozzles. The chicken carcasses were completely cleaned by applying the cabinet, leaving no blind angles. A significant reduction in microbial counts on the chicken carcasses was observed after spraying with this cabinet combined with decontamination measures during post-evisceration and post-chilling procedures, and a total bacterial count reduction of approximately 0.5 log CFU/cm^2 was obtained by spraying with water alone. A microbial reduction of almost 1.0 log CFU/cm^2 or MPN/cm^2 was observed in chicken carcasses after spraying with acidic electrolyzed water (AEW) or slightly acidic electrolyzed water (sAEW) for 15 s. In addition, 30 mg/L of sAEW was as effective as 60 mg/L of AEW in the reduction of microorganism counts. These findings indicate that sAEW may be a promising substitute for traditional sodium hypochlorite in the decontamination of chicken carcasses during slaughter, which may also help poultry companies minimize production costs in carcass decontamination.

1. Introduction

Poultry is the most popular meat worldwide due to its high nutrition; global consumption was approximately 115 million tons in 2016 and is expected to reach more than 130 million tons by 2025, as forecasted by the Organization for Economic Co-operation and Development and Food and Agriculture Organization (OECD-FAO) Agricultural Outlook (http://www.wattagnet.com/meat-market-data). China has the third highest chicken consumption, accounting for 13.86% of the total worldwide consumption of chicken meat in 2016 (https://www.fas.usda.gov/about-fas), just slightly lower than 14.55% for Brazil and 20.58% for the U.S. Currently, the short shelf-life of meat is the most common challenge for the chicken processing industry in China, especially since the consumption pattern has transformed from "sold as live chicken and slaughtered in a wet market" to "slaughtered in large-scale plants and sold as chilled meat", i.e., the new pattern advocated by the Chinese government nationwide since 2015. Numerous findings have demonstrated that more than 4.5 log CFU/g of microorganisms is usually found on whole chicken carcasses (Bartenfeld et al., 2014; Duan, Wang, Xue, Li, & Xu, 2017; Kim, Park, Lee, Owens, & Ricke, 2017) because a whole slaughter-line (Fig. 1) includes several procedures frequently associated with bacteria cross-contamination, such as de-feathering, evisceration, washing and chilling. Thus, the minimization of microbial contamination on carcasses is important during processing in slaughterhouses, for delaying the spoilage of meat and extending its shelf-life.

Water spray and immersion are usually applied to reduce microorganism levels on chicken carcasses during commercial slaughter. Water spray carried out with several simple nozzles is commonly performed between evisceration and chilling in most slaughter plants in China, which results in only limited

* Corresponding author.
E-mail address: huuwang@njau.edu.cn (H. Wang).

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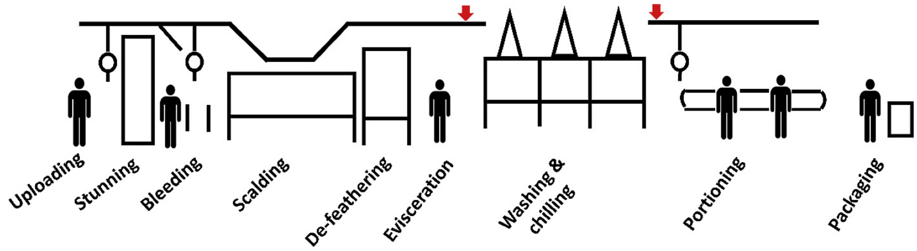

Fig. 1. The general procedures of chicken slaughter.

decontamination. Moreover, although there are variables in the spray cabinets used in poultry slaughter in plants, several shortcomings are widespread in these cabinets, such as their ineffectiveness for decontaminating inside the carcass, the use of few nozzles and limited cleaning durations or angles (Purnell, James, James, Howell, & Corry, 2014; Pordesimo, Wilkerson, Womac, & Cutter, 2002; Stefani et al., 2014). Meanwhile, some cabinets cannot achieve online cleaning, and the carcasses unloaded from the slaughter-line are passed through a spray cabinet on transmission belts (Hawkins, Vimini, Schwarz, Nichols, & Parveen, 2016). Immersion decontamination is usually combined with the chilling, in which the carcasses are immersed for 20 min in chilled water containing 50–100 mg/kg sodium hypochlorite. However, the decontamination ability of sodium hypochlorite can rapidly decline due to the reaction of available chlorine with organic matter from the exudates of the meat tissues. Therefore, the reduction of microorganisms by immersion is limited, and the immersion water itself can become a major source of bacteria cross-contamination (Banach, van Bokhorst-van de Veen, van Overbeek, van der Zouwen, van der Fels-Klerx, & Groot, 2017). A common measure for preventing carcass contamination during immersion is to continuously supply large volumes of sodium hypochlorite in the water tanks. However, the prevalence of disinfection by-products derived from chlorine-based disinfectants has been highlighted as a problem, and potential risks have been identified in the use of sodium hypochlorite in the poultry industry, with recent studies verifying that sodium hypochlorite can produce carcinogenic and mutagenic chlorinated compounds, including trihalomethanes, haloacetic acids and chloramines, by reacting with organic molecules (Bull et al., 2011; Gil, Marín, Andujar, & Allende, 2016; Legay, Rodriguez, Serodes, & Levallois, 2010). Some countries such as Belgium, Denmark and Germany have already prohibited the application of sodium hypochlorite during poultry slaughtering due to the harmful by-products of disinfection (Meireles, Giaouris, & Simoes, 2016). Therefore, much research has focused on seeking a substitution for sodium hypochlorite in the poultry industry.

Several disinfectants have been widely applied to reduce microorganisms during meat processing due to their availability, low cost and high disinfection efficacy (Bolton, Meredith, Walsh, & McDowell, 2014; Mansur, Tango, Kim, & Oh, 2015; Singh, Lee, Silva, Chin, & Kang, 2017; Sohaib, Anjum, Arshad, & Rahman, 2016). Banach et al. (2017) evaluated the efficacy of chlorine dioxide solution on the reduction of *E. coli*; the effects of lactic acid on the reduction of microbial counts on broiler carcasses have also been widely explored (Burfoot & Mulvey, 2011; Burfoot et al., 2015). However, most of these current findings were obtained in research laboratories, and some decontamination interventions may cause certain adverse effects on the appearance of carcasses. Recently, electrolyzed water, including acidic electrolyzed water (AEW) and slightly acidic electrolyzed water (sAEW), has been widely identified as an alternative disinfectant to chlorine for use in the food industry, since only salt and water are used to produce the disinfectants, which may benefit the environment and human health (Northcutt, Smith, Ingram, Hinton Jr., & Musgrove, 2007). In addition, electrolyzed water may not result in offensive and harmful odors or unacceptable color or appearance compared to other chlorine-based disinfectants (Meireles et al., 2016). Electrolyzed water has already been approved by the FDA for use as a food detergent in America. In our previous work, AEW and sAEW were demonstrated as ideal alternative disinfectants, not only reducing the initial microbial load and extending the shelf-life of chicken carcasses but also maintaining the sensory characteristics of meat (Duan et al., 2017). The present study was therefore conducted to 1) design a novel spray cabinet to reduce the bacteria load on chicken carcasses, which could be potentially applied on-line in large-scale slaughter plants to a wide variety of poultry, with efficiency and versatility in decontamination without blind angles, achieved through the adjustment of spray parameters (time and nozzles) and 2) assess the practical efficiency of microorganism reduction by a combination of cabinet use and electrolyzed water. The findings of this study could benefit companies who use such cabinet in large-scale poultry plants.

2. Materials and methods

2.1. Design concepts and principles

The spray cabinet was designed based on the following considerations: 1) applied in a large-scale chicken slaughter-line, rather than as a laboratory model; 2) capable of maintaining a certain spray time (more than 5 s) under the speed of a transmission chain (0.25–0.33 m/s); 3) washes whole chicken carcasses on-line with no blind angles; 4) anti-corrosive with flexible nozzle adjustments as needed.

In China, the production capacity of chicken slaughter for most commercial large-scale plants ranges from 6000 to 8000 heads per hour, and the distance between two adjacent carcasses is approximately 15.2 cm in a standard slaughter-line. The maximum spray time was designed to be 15 s, and the spray pressure and flow at each nozzle should be 0.3 MPa and 3 L/min, respectively, to guarantee the reduction of bacteria loading on the carcasses. The design and manufacture of the cabinet are based on the structure and units shown in Fig. 2.

2.2. Pressure and flow testing

Digital pressure gauges (XD-138, XinDa, Taizhou) and electronic fuel meters (OGM, Xinlan, Jinhua) were individually installed at proximal and distal water inlets of the up-, side- and down-spray units. The pressure and flow of corresponding nozzles were recorded after the spray cabinet was operated normally for 5 min.

2.3. Electrolyzed water preparation

AEW was produced by the electrolysis of 5% NaCl solution using an XL-150 electrolyzed water generator (Baoji Xinyu Optics-