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Application of disinfectant sprays after chilling to reduce the initial microbial load and extend the shelf-life of chilled chicken carcasses

Debao Duan [a], Huhu Wang [a], Siwen Xue [b], Ming Li [b], Xinglian Xu [a, *]

[a] Key Laboratory of Meat Processing and Quality Control, MOE, Nanjing Agricultural University, Nanjing 210095, China
[b] Jiangsu Collaborative Innovation Centre of Meat Production and Processing, Nanjing Agricultural University, Nanjing 210095, China

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A B S T R A C T

The objective of this study was to evaluate the effects of various disinfectant sprays on initial microbial load and conduct a shelf-life study of chilled chicken carcasses. Chilled chicken carcass samples obtained after chilling were sprayed for 15 s in a purpose-built spray rig with sodium hypochlorite (SH, 50 & 100 mg/L), chlorine dioxide (CD, 50 & 100 mg/L), lactic acid (LA, 1 & 2%), acid electrolyzed oxidizing water (AEOW) and slightly acid electrolyzed oxidizing water (SAEOW). Untreated carcasses were used as the control. Back, leg and breast skin were removed from each carcass after treatment to determine the total viable counts (TVC) and total coliforms. Sprays of 2% LA, AEOW and SAEOW were the most effective treatments with reductions of 0.47–0.83 log CFU/cm^2 and 0.49–0.96 log MPN/cm^2 in TVC and total coliforms, respectively. Samples treated with AEOW and SAEOW had 2 days of microbial shelf-life extension compared to the controls, which exceeded the TVC limit of 7 log CFU/cm^2 at day 6. Even longer extension was obtained for the 2% LA treated samples. The total coliforms, pH and total volatile basic nitrogen (TVBN).

TVBN values of the 2% LA, AEOW and SAEOW treated samples were significantly ($P < 0.05$) lower than those of the controls during storage. Predominantly, the TBARS values of the AEOW and SAEOW treated samples were not statistically different from those of the controls ($P > 0.05$); however, the 2% LA treatment accelerated lipid oxidization, manifested as the highest TBARS value (2.09 mg MDA/kg) at day 8. Conclusively, this study indicated that the application of AEOW and SAEOW sprays to chilled chicken carcasses after chilling can reduce initial microbial load and maintain quality attributes during refrigerated storage.

1. Introduction

High microbial contamination levels of chicken carcasses have become an imperative issue as chicken meat would spoil rapidly and lose safety when contaminated with excessive microorganisms. The microbial contamination of chicken is an economic burden that may lead to huge financial losses to producers and cause health problems for consumers (Petrou, Tsiraki, Giatrakou, & Savvaidis, 2012). Consequently, the strict application of good hygienic decontamination interventions to limit the contamination level during the slaughtering process represents a major task for chicken producers. (Bolton, Meredith, Walsh, & McDowell, 2014; Zaki, Mohamed, & El-Sherif, 2015).

Disinfectant selection is the basis of the decontamination intervention. Sodium hypochlorite (SH) is one of the most commonly used disinfectants for commercial poultry processing because of its efficacy, availability, and low cost. However, its effect decreases rapidly with organic load (Wang, Feng, & Luo, 2006). Moreover, there have been some health concerns due to the carcinogenic potential of its by-products such as trihalomethanes (Singh, Singh, Bhunia, & Stroshine, 2002). Therefore, it is necessary to seek alternative disinfectants. Chlorine dioxide (CD) and lactic acid (LA) were reported to have broad bactericidal effects with several advantages over chlorinated water, including lower toxicities, more stable forms, making them promising candidates for replacing chlorinated water in the field of chicken processing (SCVPH, 2003; Burfoot & Mulvey, 2011). Acid electrolyzed oxidizing water (AEOW) has also attracted interest as a novel disinfectant, which was reported to have strong bactericidal effects on a variety of microorganisms that are important in the food industry

* Corresponding author.
E-mail address: xlxus@njau.edu.cn (X. Xu).

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(Rahman, Khan, & Oh, 2016). Passing a diluted salt solution through an electrolytic cell within a membrane between two electrodes, an electrolyzed acidic solution is generated in the anode with a pH value of lower than 2.7, a high oxidation reduction potential (ORP) greater than 1100 mV and an approximately 50 ± 10 mg/L available chlorine concentration (ACC). It represents a green cleaning alternative to the traditional toxic disinfectants because of its environmentally friendly and economic properties (Hricova, Stephan, & Zweifel, 2008). However, some defects that would limit its application exist such as corrosion and instability (Alhaq, Sugiyama, & Isobe, 2005). In contrast, slightly acid electrolyzed oxidizing water (SAEOW) is another type of electrolyzed water that also shows considerable bactericidal effects at a pH of 5.0–6.5, an ORP of 750–850 mV, and an available chlorine concentration (ACC) of 10–30 mg/L. SAEOW is a disinfectant of more stable form and low corrosiveness, which makes it more ideal applicant during food processing (Guentzel, Kang, Callan, Emmons, & Dunham, 2008). Previously published studies on the effect of these disinfectants on raw meat are list in Table 1.

In addition to the selection of disinfectants, the application point and manner should also be taken into consideration. In the general chicken slaughter line, cleaning and disinfection are usually carried out in 3 sections: 1) during scalding, 2) after evisceration and 3) in the chiller tanks. However, the high frequency of cross-contamination and organic load accumulation in these stages may impair the decontamination efficacy, hence leading to high microbial contamination levels in the final product. Therefore, the complementary decontamination intervention after the chiller as part of multiple sequential interventions is necessary to improve a weak point in the slaughter process (Oyarzabal, Hawk, Bilgili, Warf, & Kemp, 2004; Smith, 2015).

The application of a disinfectant wash process to chilled carcasses, considered as a complement to the whole decontamination system, helps eliminate microorganisms that survived until the end of the process. This intervention is ordinarily conducted in a smaller post-chill immersion tank installed directly after the primary chiller tanks using a shorter dwell time (generally < 30 s) with a higher concentration of disinfectants. Compared with the substantial-period primary chiller, which usually lasts about 1 h, a shorter-term post-chill disinfectant wash may be more effective and economical, as well as avoiding inducing negative sensory changes to the carcasses. Additionally, since most of the soluble organic matter has been washed away from the carcasses by the counter-current water flow of the primary chiller, the efficacy of some disinfectants is more favorably enhanced at this step. (Chen et al., 2014; Nagel, Bauermeister, Bratcher, Singh, & Mckee, 2013). The majority of studies have focused on investigating the efficacy of disinfectant dipping or immersion on chilled chicken carcasses, yet few have addressed the efficacy of a disinfectant spray on chilled carcass. Compared with dip and immersion treatments, spraying would be easier to implement with respect to mobile chicken slaughter operations, and reduces water consumption and by-products formation of the disinfectants (Purnell, James, James, Howell, & Corry, 2013; EFSA 2005).

Although several previous studies have evaluated the decontamination effects of these disinfectants on raw chicken carcasses after chiller, few studies addressed their effects on either initial microbial load or shelf-life of chicken carcasses. Of these published studies, which implemented post-chill decontamination intervention, most were on the laboratory scale and adapted inoculated samples. Studies focus on comparing the efficacy of these disinfectants on naturally whole chilled chicken carcasses by post-chill spray intervention were seldom reported.

Therefore, the objectives of this study were as follows: 1) to compare various disinfectant sprays including SH (50 & 100 mg/L), CD (50 & 100 mg/L), LA (1 & 2%), AEOW and SAEOW on the initial microbial reduction on chilled chicken carcasses; 2) to select the highly efficient disinfectant treatments and investigate their effects on the shelf-life extension of chicken carcasses stored at 4 °C.

2. Material and methods

2.1. Carcass and disinfectant preparation

White-feathered chickens, consumed extensively worldwide, and Yellow-feathered chickens, which is a traditional special breed in the Chinese poultry system, were included in this study. The breed of white-feathered chickens used in our experiments were AA broiler and the breed of yellow-feathered chickens were Qingyuan Partridge and the major differences between the two chicken breeds are in their growth environment and growth rate. Compared with the White-feathered chicken, which is kept in

Table 1
Previously published studies on the effect of sodium hypochlorite (SH), chlorine dioxide (CD), lactic acid (LA), acid electrolyzed water (AEOW) and slightly acid electrolyzed water (SAEOW) on raw meat.

Disinfectants	Treated material	Application	Concentration	Exposure time	Reduction	Microorganism	Reference
SH	Chicken	Dip, Spray	50 mg/L	5 min	0.87–0.90 log CFU/g	TVC	Sinhamahapatra et al. (2004)
SH	Chicken	Immersion, spray	50 mg/L	15 s	0.30–1.17 log CFU/g	TVC	Fabrizio, Sharma, Demirci, and Cutter, (2002)
SH	Chicken	Immersion	100 mg/L, 200 mg/L	5 min	0.41–0.83 log CFU/g	*Salmonella*	Lee, Park, Kang, & Ha, (2014)
SH	Pork	Dip	100 mg/L	5 min	1.04 log CFU/g	TVC	Rahman, Wang, and Oh, (2013)
CD	Chicken	Dip	50 mg/L	15 min	0.25–0.79 log CFU/cm^2	*L.monocytogenes*	Alonso-Hernando, Alonso-Calleja, and Capita, (2015)
CD	Chicken	Spray	100 mg/L	15,30 s	0.13–0.51 log CFU/g	*Campylobacter* and *Enterobacteriaceae*	Purnell et al. (2013)
LA	Chicken	Dip	1%, 2%	1,3 min	2.05–5.01 log CFU/cm^2	*Salmonella enterica*	Zaki et al. (2015)
LA	Chicken	Dip	2%	10 min	1.22 log CFU/g	TVC	Morshedy and Sallam (2009)
AEOW	Chicken	Dip,Spray	50 mg/L	3 min	0.35–1.31 log CFU/carcass	*Campylobacter*	Rasschaert et al. (2013)
AEOW	Chicken	Immersion, spray	50 mg/L	15 s	0.19–1.34 log CFU/g	TVC	(Fabrizio et al., 2002)
AEOW	Pork	Dip	30 mg/L	3 min	1.20–1.43 log CFU/g	*S. Typhimurium*	Mansur et al. (2015)
SAEOW	Pork	Dip	30 mg/L	3 min	1.19–1.55 log CFU/g	*S. Typhimurium*	Mansur et al. (2015)
SAEOW	Chicken	Dip	10 mg/L	10 min	1.39, 2.32 and 1.92 log CFU/g	TVC, *L. monocytogenes* and *Salmonella typhimurium*	Rahman et al. (2012)