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Full Length Research Paper

Effects of lactic acid, fumaric acid and chlorine dioxide on shelf-life of broiler wings during storage

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In this study, effects of chlorine dioxide (0.3 and 0.5%), lactic acid (0.5 and 1.0%) and fumaric acid (0.5 and 1.0%) on the shelf-life of broiler wings were investigated. The samples were dipped into the experimental solutions for 10 min. and stored at +4°C for 9 days. Microbiologically, the counts of total aerobic mesophilic bacteria (TAMB), total psychrophilic bacteria (TPB) and *Escherichia coli* were determined and pH values were measured. Compared to the control samples, the TAMB counts were reduced approximately as 13% with chlorine dioxide, 13.5% with lactic acid and 10.5% with fumaric acid. The most effective bacterial reduction on *E. coli* was observed in the samples treated with 1.0% of lactic acid as 56 and 1.0% of fumaric acid as 34%. Statistically, the changes determined in the TPB counts were not significant (*P>0.05*), however they increased as 6 and 7% during the storage. Throughout the storage, the bacterial growth was reduced parallel to the concentration of the chemicals increased. The shelf-life of broiler wings was prolonged 4 days by the experimental solutions. Neither off-flavor nor a negative effect was observed on the sensorial properties by the panelists due to chemical applications.

Key words: Broiler, chlorine dioxide, lactic acid, fumaric acid, antimicrobials.

INTRODUCTION

The pathogenic and harmful bacteria that are present in the interior organs, on the skin surface and the feather of chickens, can be easily contaminated to the meat during processing steps. The bacterial contamination can be mostly seen in the production stages such as boiling, tearing the feathers, and removing of the interior organs. In addition to this, cross contamination from the skeleton, the process water and the equipment can also lead to increase in the contamination level (Graham et al., 2002; Tosun and Tamer, 2000). The mechanisms of carcass contamination and distribution over a chicken carcass are quite specific. There is retention of bacteria in a liquid film on the skin (EFSA, 2005). In order to prevent the microbial growth in the chicken meat, some chemicals like chlorine and chlorine compounds (Erickson, 1999),ozone (Whistler and Sheldon, 1989), trisodium phosphate (Rio et al., 2006) and organic acids (Graham et al., 2002) have been widely used for the deconta-mination purposes. Cooling water with chlorine dioxide has been used to reduce microbial load in red and white meat carcasses. The chlorine inhibits glucose oxidization in the metabolism of bacteria and therefore leads to the bactericidal effect. On the other hand, some toxic and carcinogenic compounds like tri-halo methane can be formed as a result of excessive usage of chlorine and react with the meat (Oguz and Guler, 2004).

The chlorine dioxide can be effective against the many pathogens even in low concentrations. It has no taste and odor. It is active to many bacteria, moulds, yeasts, algae and bio-films even in low and high pH values. The chlorine dioxide does not react with the ammonia and the compounds that can lead to form chloramines and tri-halo methanes (Andrews, 2002). Organic acids are used for lowering the initial microbial load of the broilers to prolong their shelf life. The most common organic acids used as antimicrobial are acetic acid, lactic acid, propionic acid,

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Abbreviations: TAMB, Total aerobic mesophilic bacteria; **TPB,** total psychrophilic bacteria; **MRD,** maximum recovery diluent; **TBX,** tryptone bile x-glucuronide.

Table 1. Effects of chlorine dioxide, lactic acid and fumaric acid on the TAMB counts (log cfu/g) in the chicken wings (mean ± SE).

Dipping solutions (%)	Storage days at 4ºC				
	1	3	5	7	9
CD (0.5)	$4.36±0.17^{ab}$	$4.60±0.03^{a}$	$4.90±0.02^{a}$	$5.24±0.01^{a}$	$5.54±0.02^{a}$
CD (0.3)	$4.44±0.20^{b}$	$4.62±0.01^{a}$	$5.12±0.03^{b}$	$5.38±0.01^{c}$	$5.75±0.01^{b}$
LA (1)	$4.35±0.01^{a}$	$4.61±0.08^{a}$	$5.27±0.33^{ab}$	$5.32±0.02^{b}$	$5.62±0.01^{a}$
LA (0.5)	$4.39±0.01^{ab}$	$4.91±0.05^{b}$	$5.26±0.01^{ab}$	$5.44±0.03^{d}$	$5.79±0.02^{b}$
FA (1)	$4.55±0.02^{c}$	$4.93±0.08^{b}$	$5.27±0.05^{ab}$	$5.45±0.02^{d}$	$5.69±0.05^{b}$
FA (0.5)	$4.44±0.02^{b}$	$4.92±0.06^{b}$	$5.21±0.03^{ab}$	$5.37±0.05^{c}$	$5.66±0.03^{ab}$
Control	$4.96±0.01^{d}$	$5.31±0.08^{c}$	$5.87±0.02^{c}$	-	-

The means with the different letters in the same column are different, statistically (*P<0.05*) and (n=27). FA: Fumaric acid, CD: Chlorine dioxide, LA: Lactic acid.

sorbic acid and benzoic acid. However, antimicrobial activity of these acids can be limited (Davidson, 2001). The initial microbial load or/and contamination is one of the main factors that affects to prolong the shelf-life of many food products. For this reason, the lowering of initial microbial load or/and preventing the contamination during processing are very important need in the perishable food products like pieced chicken (Ugur et al., 1995). Mesophilic bacteria, psychrotrophs, coliforms, *E. coli* and *Staphylococcus aureus* have been used to evaluate microbiological safety, hygienic quality during processing and storage in poultry products (Alvarez-Astorga et al., 2002). The objective of this study was to investigate the effectiveness of chlorine dioxide, lactic acid and fumaric acid to improve the microbial quality and enhance the shelf-life of chicken wings during the storage.

MATERIALS AND METHODS

The chicken wings of broilers from slaughtered 6 to 8 weeks old broilers were used in our research. They were immediately used after the slaughtering for the dipping treatments and stored at 4°C during the storage. The wings untreated with chemical solutions used as control were washed with pressurized water at 15°C for 1 min. For each trial, 50 samples were used and dipped into 1% and 0.5% of lactic acid (Sigma-Aldrich, St. Louis, MO, USA), 1 and 0.5% of fumaric acid (Sigma-Aldrich, St. Louis, MO and USA) and 0.3 and 0.5% of chlorine dioxide solutions for 10 min under laboratory conditions (Carpenter et al., 2011). The experimental chlorine dioxide solutions were obtained by using stabilized chlorine dioxide stock solution (2%, Oxine, Bio-cide International, Oklahoma, USA). The analyses were continued until 9^{th} day of storage under refrigeration at 4°C.

Microbiological enumeration

Twenty-five grams of de-boned wing sample were homogenized in 225 ml of Maximum Recovery Diluent-(MRD) (Oxoid, CM0733B) by blending (Patterson and Cassells, 1963). The other decimal dilutions were also prepared in MRD. Standard Plate Count Agar (Oxoid, CM0463) was used in order to enumerate the TAMB and the TPB. The inoculated plates were incubated at 30°C for 72 h and 7°C for 10 days, respectively (Downes and Ito, 2001). Tryptone Bile X-glucuronide Medium-TBX (Oxoid, CM0945) was used for the enumeration of *E.coli* (ISO, 2001). The incubation was done at 44°C for 18 to 24 h.

Sensorial analysis

The samples were evaluated by 8 experienced panelists according to Kolsarici and Candogan (1995) with slight modification. The scores were referred as following; (1) the worst, (2) very bad, (3) bad, (4) below medium, (5) medium, (6) above medium, (7) good, (8) very good and (9) the best. Before the taste panel, the samples were cooked in the oven at 200°C for 35 to 40 min until the internal temperature of the samples reach to 85°C. Hanna pH 211/213 model pH meter was used for pH measurements. Before measuring the pH value, the samples were homogenized with neutral saline water. ANOVA (Analysis of Variance) was used to determine the differences between the means by using statistical software (SPSS for Windows, Release 15.0).

RESULTS

Comparing to the control samples, the counts belonging to the TAMB were reduced as 12 and 14% with chlorine dioxide treatment, 13 and 14% with lactic acid treatment and 9 and 12% with fumaric acid treatment at the initial day (Table 1). According to Turkish Food Codex (TFC, 2006), the microbial limits were exceeded in the control samples after 5^{th} day of the storage. The control samples lost their organoleptic properties and hygienic quality after this period as parallel with the microbial growth. During the storage period, TAMB counts were increased 27 and 29% in 0.5 and 0.3% of chlorine dioxide, 29 and 32% in 1.0 and 0.5% of lactic acid and 25 and 27% in 1.0 and 0.5% of fumaric acid, respectively. *E. coli* counts of the control group were changed between 2.80 and 3.15 log cfu/g, while the counts of other samples were between 1.79 and 2.92 log cfu/g (*P<0.05*). The most effective treatments were 1% of lactic acid solution and 1% of fumaric acid solution. The *E. coli* counts were reduced as 11 and 28% with chlorine dioxide solution (0.3 and 0.5%), 16 and 56% with lactic acid solution (0.5 and

Table 2. Effects of chlorine dioxide, lactic acid and fumaric acid on the *E. coli* counts (log cfu/g) in the chicken wings (mean ± SE).

Dipping solutions	Storage days at 4ºC				
	1	**3**	**5**	**7**	**9**
CD (0.5%)	2.18±0.03^{c}	2.34±0.03^{c}	2.40±0.03^{c}	2.51±0.02^{c}	2.63±0.02^{c}
CD (0.3%)	2.52±0.02^{d}	2.57±0.03^{d}	2.64±0.02^{d}	2.88±0.03^{d}	2.92±0.06^{d}
LA (1%)	1.79±0.06^{a}	1.93±0.03^{a}	1.980±0.03^{a}	2.03±0.01^{a}	2.13±0.03^{a}
LA (0.5%)	2.40±0.02^{d}	2.43±0.01^{c}	2.52±0.08^{c}	2.60±0.08^{c}	2.67±0.05^{c}
FA (1%)	2.09±0.04^{b}	2.18±0.02^{b}	2.22±0.01^{b}	2.25±0.01^{b}	2.33±0.06^{b}
FA (0.5%)	2.27±0.02^{c}	2.35±0.06^{c}	2.46±0.06^{c}	2.57±0.03^{c}	2.65±0.03^{c}
Control	2.80±0.05^{e}	2.91±0.04^{e}	3.15±0.04^{e}	-	-

The means with the different letters in the same column are different, statistically ($P<0.05$) and (n=27). FA: Fumaric acid, CD: Chlorine dioxide, LA: Lactic acid.

Table 3. Effects of chlorine dioxide, lactic acid and fumaric acid on the TPB counts (log cfu/g) in the chicken wings (mean ± SE).

Dipping solutions	Storage days at 4ºC				
	1	**3**	**5**	**7**	**9**
CD (5%)	5.38±0.06^{a}	5.24±0.03^{a}	5.44±0.03^{a}	5.62±0.03^{a}	5.72±0.03^{a}
CD (3%)	5.43±0.06^{c}	5.31±0.01^{a}	5.45±0.05^{a}	5.67±0.03^{b}	5.77±0.03^{b}
LA (1%)	5.40±0.06^{b}	5.17±0.08^{a}	5.47±0.02^{ab}	5.65±0.08^{ab}	5.77±0.08^{b}
LA (0.5%)	5.41±0.04^{c}	5.27±0.05^{b}	5.52±0.05^{b}	5.67±0.05^{b}	5.75±0.02^{b}
FA (1%)	5.40±0.06^{b}	5.28±0.06^{b}	5.47±0.03^{ab}	5.65±0.03^{ab}	5.74±0.01^{ab}
FA (0.5%)	5.47±0.06^{d}	5.32±0.08^{b}	5.58±0.06^{c}	5.71±0.05^{c}	5.77±0.01^{b}
Control	5.63±0.06^{e}	5.52±0.08^{c}	5.70±0.02^{d}	-	-

The means with the different letters in the same column are different, statistically ($P<0.05$) and (n=27). FA: Fumaric acid, CD: Chlorine dioxide, LA: Lactic acid.

1.0%) and 23 and 34% with fumaric acid solution (0.5 and 1.0%) at the initial day, respectively. At the beginning of storage, pH values were 6.12 and 6.10 in the samples treated with 0.3 and 0.5% of chlorine dioxide, 5.60 and 5.10 in the samples containing 0.5 and 1.0% of lactic acid and 5.8 and 5.5 in the samples containing 0.5 and 1.0% of fumaric acid, respectively. pH value of the control sample was 6.20. We found that the pH values of the samples were far from the 6.4 pH which has been assumed as critical point for meat in terms of occurrence of initial spoilage, even at the end of the storage.

DISCUSSION

During the storage, the counts of *E. coli* increased 15 and 20% in chlorine dioxide, 11 and 19% in lactic acid and 11 and 16% in fumaric acid in spite of the chemical solutions used (Table 2). According to Tosun and Tamer's study (2000), each carcass had 1.259 log reduction for mesophilic bacteria count TMAB and 2.023 log reduction for *E. coli* count when 1% concentrated lactic acid applied. At the beginning of the storage, the TPB counts were reduced approximately 3 and 4% with the organic acids and chlorine dioxide (Table 3). Van der Marel et al. (1988) who studied on the microbiological quality of chicken carcasses treated with 1 and 2% of concentrated lactic acid found that, mesophilic TAMB) and physicrophilic bacteria TPB counts with Enterobacteriaceae and *S. aureus* counts were reduced 1 log cfu/g. Undesired and unprevented microbial availability can be explained by the following reasons. Dipping into the chemical solutions can be effective to minimize contamination, but is not fully effective especially in exposed areas of connective tissue that are more heavily contaminated.

In general, decontamination treatments are able to reduce the contamination level but do not completely eliminate pathogens. Their effectiveness depends on the initial microbial load and treatment conditions. There are many factors affecting the efficacy of these antimicrobials including concentration of the substance, time of exposure, temperature, pH and hardness of water, strength of bacterial adhesion to the carcasses, bio film formation and the presence of fat or organic material in water (EFSA, 2005). No adverse effect related with the dipping treatments on sensory properties of chicken wings was reported by the panelists (Table 4). Similarly, Mulder et al. (1987) reported that a little color loss was obtained in 0.5 and 1% concentrated lactic acid

Table 4. Sensorial properties of the chicken wings treated with chlorine dioxide, lactic acid and fumaric acid (mean ± SE).

Dipping solutions (%)	Sensorial properties[a]				
	Color	**Appearance**	**Odor**	**Brittleness**	**General acceptability**
CD (5%)	6.94±0.17	7.31±0.20	7.13±0.20	6.81±0.16	6.81±0.16
CD (3%)	7.00±0.13	7.56±0.18	7.13±0.20	6.81±0.16	6.88±0.15
LA (1%)	6.63±0.12	7.44±0.17	6.88±0.12	6.94±0.17	6.69±0.15
LA (0.5%)	7.06±0.14	7.44±0.16	7.00±0.16	6.81±0.14	6.81±0.14
FA (1%)	6.81±0.164	7.38±0.20	6.88±0.18	7.00±0.16	7.02±0.16
FA (0.5%)	6.88±0.155	7.25±0.17	6.94±0.17	6.88±0.15	7.00±0.18
Control (Untreated	7.13±0.15	7.44±0.16	7.25±0.19	7.03±0.18	7.00±0.15

FA: Fumaric acid, CD: Chlorine dioxide, LA: Lactic acid.

application, but no negative effect was seen on odor. Snijders et al. (1985) reported that 1 and 2% concentrated lactic acid application after slaughtering had no effect on the sensorial properties and aroma of meat. Uğur et al. (1995) reported that chicken carcasses plunged into 0.1, 0.3 and 0.6% concentrated lactic acid and acetic acid had no effect on skin color, taste and odor of chicken carcasses.

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