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Application of electrolyzed water for improving pork meat quality

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ABSTRACT

The microbiological and oxidative qualities of pork loin sprayed with different types (slightly acidic, acidic and basic) and combinations of electrolyzed water (EWs) were evaluated. The EWs were applied at two temperatures (18° and 30 °C) and pressures (30 and 45 psi) and the volume corresponded to approximately 10% water commonly used in carcass washing. EW after spraying exhibited a chlorine concentration between 15 and 25 ppm. The application of acidic EW (AEW) alone or in combination with basic EW (BEW) decreased ($P < 0.05$) the microbial counts shortly after spraying. In addition, the combination of BEW + AEW (30 psi) reduced the mesophilic and psychrotrophic bacteria counts throughout the refrigerated storage ($P < 0.05$). The EWs did not increase the lipid oxidation of the samples. On the other hand, a high protein oxidation was observed in the samples sprayed with AEW and slightly acidic EW (SAEW), while BEW was effective to reduce the oxidation reactions. Therefore, the results showed that the combination BEW + AEW may be a viable alternative to reduce the volume of water used at slaughter and to improve the microbiological quality of pork meat.

1. Introduction

Washing of pork carcasses after toileting prior to refrigerated storage is performed in most industries, using water at room temperature and pressure of 3 atm, and a large amount of water per carcass (Cattani, 2012). Electrolyzed water (EW) is an emerging technology with potential for industrial application because it returns to its original state after application since chlorine species are consumed during contact with organic matter (Al-Haq, Sugiyama, and Isobe, 2005). The acidic EW (AEW) has pH between 2 and 3 and oxi-reduction potential (ORP) > 1000 mV, whereas the slightly acidic electrolyzed water (SAEW) has pH between 5 and 7 and ORP of 800–900 mV, and the basic EW (BEW) has pH 10–12 and ORP < − 600 mV. Various chlorine concentrations (CLC) can be found in different types of EW, as it is influenced by the brine concentration, electrolysis time, and electric current applied (Hsu, 2005). The main form of chlorine in AEW is Cl_2, while the hypochlorous acid (HOCl) and hypochlorite (OCl) are most present in SAEW and BEW, respectively (Rahman, Ding, and Oh, 2010).

The effect of EW on the reduction of microbial counts in several foods has been widely studied (Cao, Zhu, Shi, Wang, and Li, 2009; Jadeja & Hung, 2014), which is more effective when compared to sodium hypochlorite and peroxyacetic acid (Cao et al., 2009; Mártinez-Hernández et al., 2015). However, most of the studies evaluated the use of one type of EW alone as a way to reduce microbial counts in foods (Rahman, Park, Song, Al-Harbi, and Oh, 2012), and the combination of different types of EW has not been studied. In addition, there is little information in the literature about the effect of EW on lipid and protein oxidation of meat. On the other hand, immersion is the main form of application of EW (Fabrizio & Cutter 2005, Cao et al., 2009; Xu et al., 2014). This approach, although effective in reducing microbial counts, has the disadvantage of using large volumes of EW, which makes its industrial application impracticable in most cases. Thus, studies that aim to reduce the volume of EW and increase its antimicrobial efficiency are necessary to enable the application of this emerging technology on an industrial scale.

Based on this, different types and combinations of EW were sprayed on pork loins. The microbiological quality of the pork loins and the lipid and protein oxidation were evaluated during the refrigerated storage.

2. Materials and methods

2.1. Production of different types of EW

Different types of EW (AEW, SAEW, and BEW) were obtained from a

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0.05% sodium chloride (Dinâmica, Brazil) using a portable electrolyser (Envirolyte, Estonia). The pH and ORP were measured by direct immersion of EW using a glass electrode (Digimed, Brazil) and a platinum electrode (Digimed, Brazil), and the CLC was evaluated according to APHA (1998) methodology.

2.2. Sampling and processing

Pork loins at 38 °C ± 1 were collected on 3 different days in a slaughter in the central state of Rio Grande Sul, Brazil. The pork loins were cut in 6 units for each application (250 ± 50 g, containing skin, fat, and meat), and subjected to EW spraying. The temperature of each loin was 36 °C ± 1 at the time of application, thus simulating the washing step of the pork carcass after toileting prior to refrigerated storage. In all experiments, a 10 cm distance was used between the spray application and the loin, which was rotated at a 360° angle during application. The pressures of 30 and 45 psi were selected in previous trials. Four experiments were carried out, as follows: E1: application of AEW, SAEW, and BEW alone, at 18 °C and 30 psi for 40 s; E2: application of AEW, SAEW, and BEW alone at 30 °C and 30 psi for 40 s; E3: application of BEW for 20 s + AEW for 20 s (BEW + AEW) or application of BEW for 20 s + SAEW for 20 s (BEW + SAEW) at 18 °C and 30 psi; and E4: application of BEW for 20 s + AEW for 20 s (BEW + AEW) or application of BEW for 20 s + SAEW for 20 s (BEW + SAEW) at 18 °C and 45 psi. Each 20 s of spraying corresponded to 100 mL of EW, and a control using deionized water under similar time, temperature, and pressure conditions was performed. After application, the pork loins were vacuum packed in low-density polyethylene bags (24 μ thickness and $TPVO_2$ < 30 cm^3/m^2·day), and stored at 4 °C ± 1 for 29 days. The determinations were performed at day 1, 15, and 29 of refrigerated storage (4 °C ± 1) using 2 units for each sampling day.

2.3. Microbiological determinations

Mesophilic (MA) and psychrotrophs (PS) aerobic microorganisms were quantified using plate count agar medium (PCA, Merck, Darmstadt, Germany), lactic acid bacteria (LAB) were quantified using Man–Rogosa–Sharpe agar (MRS, Merck, Darmstadt, Germany) by plate count technique, with incubation at 36 °C for 48 h for MA and LAB, and 7 °C for 7 days for PS (APHA, 2001).

2.4. pH and redox potential (ORP)

For determination of pH and ORP, 5 g sample were homogenized with 50 mL distilled water with subsequent readings in a pH meter (Digimed, Brazil) according to AOAC (2006).

2.5. Tiobarbituric acid reactive substances (TBARS)

TBARS were determined as described by Raharjo, Sofos, and Schimidt (1992), by the reaction of 10 g sample and thiobarbituric acid (Merck, Darmstadt, Germany) at 95 °C for 5 min, followed by absorbance readings at 531 nm. The results were expressed as mg of malonaldehyde (MDA)/kg sample.

2.6. Carbonyl groups

The carbonylated proteins were determined according to Levine et al. (1990) with modifications. The protein pellets were dissolved in 2% sodium dodecyl sulfate (SDS, Sigma–Aldrich, St. Louis, MO). The samples derived from the precipitate treated with 2,4-dinitrophenylhydrazine (DNPH, Sigma–Aldrich, St. Louis, MO) were measured at 370 nm, and a blank was measured at 370 nm for protein quantification. The carbonyl group was quantified as [Abs_{370} with DNPH - Abs_{370} blank] to eliminate the effect of protein absorbance, using the molar extinction coefficient 22,000 M^{-1} cm^{-1}. The results were expressed as nano mol DNPH/mg protein.

2.7. Thiol groups

The thiol groups were evaluated according to Ellman (1959) with modifications. For quantification, the absorbance readings were compared to a cysteine standard curve. The absorbance was measured at 412 nm using an Agilent 8453 spectrophotometer (Agilent Co., Germany) after reaction with 5,5′-Dithiobis 2-nitrobenzoic acid (Sigma–Aldrich, St. Louis, MO). The results were expressed as thiol nmol/mg protein.

2.8. Color measurements

The meat was removed from the vacuum package at 20 °C (± 1). After 30 min, the color measurements were performed using a colorimeter Minolta CR400 (Konica Minolta, Japan) by direct readings of 5 random points. The illuminant A, specular component included, and 10° observer angle were used to measure the color parameters L*, a*, and b * (Brewer, Zhu, Bidner, Meisinger, and McKeith, 2001), and the red index was calculated according to a*/b* (Chen, Chiu, and Huang, 1997).

2.9. Statistical analysis

Data were analyzed by ANOVA, and the differences were analyzed using the Duncan test (P < 0.05) for comparison between means. The entire experiment was repeated three times in different days, and each analysis was carried out in triplicate, using the software STATISTICA 7.0 (StatSoft Inc., USA). The principal component analysis (PCA) charts were made with SAS.

3. Results and discussion

3.1. Characteristics of different types of EW before and after spraying

The concentration of chlorine (CLC) decreasead up to 70% after spray due the interaction between chlorine and organic matter. However, a greater reduction of CLC was observed in the EWs at 30 °C (AEW-77%, and SAEW-60%) drained from the pork loin, when compared to EWs applied at 18 °C (AEW-69%, and SAEW-51%, Table 1), once that higher temperatures favored the evaporation of Cl_2. Probably, the presence of chlorine in the AEW (23 ppm in E1, E3, and E4; and

Table 1
Characteristics of the different types of electrolyzed water used to spray the pork meat.

Experiments	pH	POR (mV)	Chlorine before spray (mg/L de Cl_2)	Post-spray Chlorine (mg/L de Cl_2)	% post-spray chlorine reduction (residual water[a])
E1 40″ 18 °C					
AEW	2.60	1185	74	23	69
SAEW	6.5	940	47	23	51
BEW	11.45	− 826	0	0	0
E2 40″ 30 °C					
AEW	2.60	1134	74	17	77
SAEW	6.41	875	38	15	60
BEW	11.40	− 877	0	0	0
E3 e E4					
AEW	2.60	1200	74	23	68
SAEW	6.15	930	51	25	51
BEW	11.40	− 830	0	0	0

Note: Results expressed as mean.
AEW: acidic electrolyzed water; SAEW: slightly acidic electrolyzed water; BEW: basic electrolyzed water.
[a] Residual water is the water that drained from the pork loin when applied.