Meat Science 123 (2017) 211–218

Contents lists available at ScienceDirect

Meat Science

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

Evaluation of alkaline electrolyzed water to replace traditional phosphate enhancement solutions: Effects on water holding capacity, tenderness, and sensory characteristics

Macc Rigdon [a], Yen-Con Hung [b], Alexander M. Stelzleni [a,*]

[a] Animal and Dairy Sciences Department, University of Georgia, 425 River Rd., Athens, GA 30602, USA
[b] Departement of Food Science and Technology, University of Georgia, 1109 Experiment St., Griffin, GA 30223, USA

ARTICLE INFO

Article history:
Received 12 April 2016
Received in revised form 5 October 2016
Accepted 13 October 2016
Available online 14 October 2016

Keywords:
Water holding capacity
Enhancement
Pork
Water
Alkaline

ABSTRACT

Sixty-four pork loins were randomly assigned to one of four treatments to evaluate the use of alkaline electrolyzed reduced water as a replacement for traditional enhancement solutions. Treatments included: alkaline electrolyzed reduced water (EOH; pH ≈ 11.5), EOH plus 2.5% potassium-lactate (EOK), industry standard (IS; 0.35% sodium tri-polyphosphate, 0.14% sodium chloride, 2.5% potassium-lactate), and no enhancement (CON). After enhancement (targeting 110%) and rest period, chops were cut (2.54-cm) to test treatment effects on water holding capacity, Warner-Bratzler shear force (WBSF), and sensory attributes. Despite its alkaline nature EOH chops exuded more water ($P < 0.05$) than EOK, IS, or CON chops. Control chops were similar ($P > 0.05$) to EOK, however CON and EOK both lost more moisture ($P < 0.05$) than IS. The use of alkaline electrolyzed reduced water did not improve WBSF or sensory characteristics compared to IS treated chops. As a stand-alone enhancement solution alkaline electrolyzed reduced water was not a suitable replacement for industry standard solutions.

1. Introduction

The commercial pork industry has taken advantage of enhancement as a process to provide consumers with more tender, juicy, and flavorful pork products (Brewer, Jensen, Prestat, & Zhu, 2002; Hayes, Desmond, Troy, Buckley, & Mehra, 2006). Typical enhancement solutions contain ingredients including water, salt, and phosphates. Additionally, enhancement solutions may contain additives such as lactates, and acetates that have been shown to improve shelf life stability, color, and flavor (Brewer, McKeith, Martin, Dallmier, & Meyer, 1991; de Wit & Rombouts, 1990; Sutton, Brewer, & McKeith, 1997). Fresh meat enhancement improves palatability largely due to: 1) disruption of the myofibrillar network via severance of the contractile, structural, and connective tissue proteins by needle penetration (Tyszkiewicz, Jakubiec-Puka, Wieczorek, & Klossowska, 1997), and 2) causing an increase in the swelling of the myofibrillar structure by increased water holding capacity due to the effect alkaline salts and phosphates have on the protein charges (Baublits, Mehaffey, Saha, Meullenet, & Sawyer, 2006; Offer & Trinick, 1983).

In the United States approximately 57% of fresh pork is enhanced (Annonymous, 2014) and of these fresh enhanced products 79.5% are enhanced by needle injection (Muth, Ball, & Coglaiti, 2012). Although salt and phosphate enhancement solutions have been widely used and have been successful in binding additional water (Ranken, 1976), the use of salt or phosphate is not always desirable (e.g. low sodium products, clean label products, and phosphates not being accepted by some countries in meat enhancement solutions). Ingredient and labeling concerns has led others to investigate substituting salt, or phosphates with other alkaline solutions including sodium hydroxide (NaOH) and ammonium hydroxide (NH_4OH; AH) in an attempt to raise the pH of the meat system for increased water holding capacity or ingredient replacement (Kingwascharapong & Benjakul, 2016; Knipe, 1982; Moiseev & Cornforth, 1997). As the consuming public becomes more circumspect of chemicals used in their foods and listed ingredients, even if they have a functional role (Brewer, 1998) and demand and willingness to pay for cleaner-label items increases (Zurawicki, 2015) the meat industry must respond to maintain viability. However, replacement ingredients must be tested and be able to retain the functionality of those they are replacing. Alkaline electrolyzed water (AEW), when produced with sodium chloride (NaCl), forms a dilute sodium hydroxide (NaOH) solution and may hold promise as a replacement of salts and phosphates in enhancement solutions by increasing the meat system pH. Alkaline electrolyzed water, which must be labeled as sodium hydroxide, is generally recognized as safe (GRAS; 21 CFR 184.1763, 21 CFR 184.1631, 9 CFR 424.21) and can be used "as a pH control agent in water used in poultry and red meat processing" at a level "sufficient for purpose" (USDA-FSIS Directive 7120.1).

* Corresponding author at: 425 River Rd., Athens, GA 30602, USA.
E-mail address: astelz@uga.edu (A.M. Stelzleni).

http://dx.doi.org/10.1016/j.meatsci.2016.10.007
0309-1740/

Electrolyzed water is produced by passing a dilute salt solution through a membrane with an electrical current flowing across the membrane producing both acidic electrically oxidized water (pH ≈ 2.5) and AEW with an approximate pH of 10.8 (Huang, Hung, Hsu, Huang, & Hwang, 2008). Acidic and alkaline electrolyzed water have shown to possess bactericidal properties when used in equipment (Venkitanarayanan, Ezeike, Hung, & Doyle, 1999) and meat (Ding, Rahman, Purev, & Oh, 2010) applications. An additional benefit of electrolyzed water is that it is easy and economical to produce and use (Kim, Hung, & Brackett, 2000). If a processor were to invest in electrolyzed water as an antimicrobial, they could potentially use both phases by incorporating the AEW phase in other areas of facility operations including enhancement solutions. Although NaOH has been successfully used to increase the pH and water holding capacity of a meat system when used in conjunction with salts or phosphates, the research is limiting on the use of NaOH alone as a total replacement of salt and phosphates. Therefore, the objectives of this study were to determine if pork loins enhanced with one of two AEW solutions were comparable to traditionally enhanced pork for water holding capacity and palatability characteristics.

Table 1
Least squares means for loin enhancement characteristics.

Traits[2]	Treatments[1] CON	EOH	EOK	IS	SEM	*P*-value
Raw wt.	3.40	3.23	3.27	3.17	0.08	0.20
Enh. wt.	3.40[b]	3.78[a]	3.74[a]	3.57[ab]	0.10	0.04
Rest wt.	3.40	3.59	3.58	3.47	0.09	0.43
PU initial, %	–	16.74[a]	13.96[b]	12.59[b]	0.71	<0.01
PU final, %	–	10.90[a]	9.26[b]	9.47[b]	0.42	<0.01
pH raw	5.80	5.75	5.66	5.85	0.07	0.29
pH enh	5.80	5.71	5.75	5.86	0.05	0.30
Cation[3], mg/kg						
Sodium	426.29[a]	454.20[a]	472.23[a]	1971.32[b]	38.07	<0.01
Potassium	3899.49[b]	3303.70[a]	8695.69[c]	8908.18[c]	191.50	<0.01

[abc] Means within a row that do not have common superscripts are different ($P < 0.05$).
[1] CON: Control; EOH: Alkaline electrolyzed water; EOK: Alkaline electrolyzed water with potassium lactate; IS: Industry standard enhancement solution.
[2] Raw wt.: Weight of pre-enhanced loins; Enh. wt.: Weight of loins immediately after enhancement; Rest wt.: Weight of enhanced loins after 15 min rest period; PU initial: Percent of moisture pickup when compared to Enh. wt.; PU final: Percent of moisture pickup when compared to Rest Wt.; pH raw: pH of the loin pre-enhancement; pH enh; pH of the loins post-enhancement.
[3] Cation values are from post rest, uncooked chops.

2. Materials and methods

2.1. Pork loin procurement and enhancement

Sixty-four Institutional Meat Purchase Specifications 413 whole boneless pork loins (longissimus thoracis et lumborum) that were considered red, firm, and normal by plant personnel were procured 2 d postmortem from a multi-national pork supplier (daily capacity >12,000 head) across two replicates (32 loins per replicate) and transported (0 ± 2 °C) 575 km to the University of Georgia Meat Science Technology Center (MSTC, Athens, GA). The pork loins for each replicate were randomly selected from the mornings fabrication line, vacuum packaged and boxed accordingly to plant standard operating procedures. Upon arrival at the MSTC, the pork loins were placed in cold (1 ± 2 °C), dark storage until 4 d postmortem. At 4 d postmortem the loins were randomly assigned to one of four treatments (8 loins/treatment · replicate^{-1} for a total of 16 loins per treatment) to test the efficacy of novel enhancement solutions on pork loin water holding capacity and palatability characteristics. The four treatments included: 1) alkaline electrolyzed reduced water (EOH; pH ≈ 11.76, 5.75×10^{-3} M NaOH), 2) EOH with 2.5% potassium lactate (EOK; pH ≈ 10.92; Hawkins, Minneapolis, MN), 3) water with 0.35% sodium tri-polyphosphate (ICL Performance Products, Bolingbrook, IL), 0.14% sodium chloride (Morton Salt Inc., Chicago, IL), 2.5% potassium lactate (IS; pH ≈ 6.78), and 4) no enhancement (CON).

Electrolyzed reduced water was produced using an electrolyzed water generator (ROX-20TA-U, Hoshizaki Electric, Japan) according to Park, Hung, and Brackett (2002) where deionized water and a dilute salt (6% NaCl) solution were simultaneously passed through a generator at approximately 18 amps and 10 V. Alkaline electrolyzed water was collected from the cathode side of the generator with an approximate pH and ORP of 11.76 and −187, respectively.

After treatment randomization whole loins where enhanced using a multi-needle injector (Injectamatic PI21, Koch Equipment LLC, Kansas City, MO, USA) to a target of 110% of raw weight followed by a 15 min rest period. The multi-needle injector was calibrated with test loins prior to each treatment application. Weights were recorded for loins prior to enhancement, immediately after enhancement, and after 15 min rest to determine immediate and final percent enhancement solution uptake (Table 1).

After the post enhancement rest period, the whole loins were cut into 2.54 cm chops. Starting from the anterior end, the loin was squared, and the squared end was used to measure pH using a pH probe (model WD-35649-50, Oakton Instruments, Vernon Hills, IL) placed directly into the muscle, and cation concentration. Two chops were removed for Warner-Bratzler shear force (WBSF), the following 7 chops were used for moisture retention/water holding capacity determination, an area of 7 chops (≈18 cm) was removed, and then two additional chops were cut for trained sensory analysis. Chops for cation, WBSF, and sensory analysis were immediately vacuum packaged (B-620 series; 30–50 cm^3 O_2/m^2/24 h/101,325 Pa/23 °C; Cryovac Sealed Air Corporation, Duncan, SC, USA) and frozen (−20 °C) until further analysis.

2.2. Cation analysis

Samples for cation analysis were thawed (0 ± 2 °C) for 24 h and then the samples were digested following the EPA Method 3052 (USEPA, 1995). Briefly, approximately 1 g of sample were weighed and placed in fluorocarbon polymer microwave vessels and had 10 mL of concentrated HNO_3 added to each vessel before sealing. The sealed vessels were placed in a microwave digester (CEM Mars 6 Microwave, Matthews, NC, USA) and heated at 200 °C for 30 min. The digests were quantitatively transferred into volumetric flasks and brought to 100 mL with deionized water. The samples were analyzed for various cations following EPA Method 200.8 (Creed, Brockhoff, & Martin, 1994) by Inductively Coupled Plasma – Optical Emission Spectroscopy (Spectro Acros FHS16, Kleve, Germany).

2.3. Water analysis

Water analysis was calculated following two methods: 1) on an individual basis where moisture loss was calculated in succession based on the chop starting weight of each assay; and 2) on a 100% basis where moisture loss was calculated as part of a whole where moisture loss from each assay contributed to the total moisture loss. Water loss on a percent basis was performed using a 100% starting weight; each subsequent assay's starting weight was based upon chop weight after total water loss to that point, as indicated by $\omega_1 = 100$; $\omega_2 = 100$ – [Free Drip on Percent Basis (FDPB)]; $\omega_3 = \omega_2$ – [expressible juice loss due to vacuum packaging on percent basis (EJVPB)]; $\omega_4 = \omega_3$ – [expressible juice loss due to gravimetric force on percent basis (EJGPB)].

2.3.1. Free drip

Free drip was measured using the methods as outlined by Honikel and Hamm (1994). Immediately after cutting, chops were weighed, then hung from a hook and placed in a whirl-pak bag (Fort Atkinson, WI) so as to not touch the meat to the bag. Chops were hung in a cooler