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Effect of sodium citrate plus sodium diacetate or buffered vinegar on quality attributes of enhanced beef top sirloins

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ABSTRACT

As new pathogen intervention products come to market, it is important to ensure that they maintain or improve meat quality. Shelf-life and palatability traits were measured for top sirloins enhanced to 110% with solutions containing 0.5% sodium chloride and 0.4% sodium tripolyphosphate (CNT); CNT with a 1% solution of 80% sodium citrate plus 20% sodium diacetate (SC + D); or CNT with 2% buffered vinegar (VIN) in the final product. Enhancement solution did not influence color over 7 days of retail display, except VIN was subjectively more red than CNT and SC + D on d 7 and SC + D had less discoloration than CNT on d 7 ($P<0.05$). VIN was rated lower ($P<0.05$) than CNT for trained sensory tenderness and there was no difference in shear force between treatments. SC + D and VIN show promise for use in beef enhancement solutions, however, further sensory studies are warranted.

1. Introduction

Consumer acceptability studies for beef palatability have reported that tenderness is the most important characteristic influencing consumer perceptions after the point of sale (Brooks et al., 2000; Morgan et al., 1991). With the centralization of meat processing facilities, rapid methods of tenderization, called whole-muscle, non-intact cuts, have been able to replace traditional beef aging processes, decreasing storage time and increasing rates of efficiency. Blade tenderization and injection of enhancement solutions are common methods employed by the meat industry to improve the tenderness and palatability of whole-muscle products (Boyd, Ockerman, & Plimpton, 1978; Davis, Huffman, & Cordray, 1975; Glover, Forrest, Johnson, Bramblett, & Judge, 1977; Wicklund et al., 2005). Furthermore, the palatability of beef from cull cows, which has been shown to be lower than beef from young steers (Stelzleni, Patten, Johnson, Calkins, & Gwartney, 2007), can be improved by enhancement (Hoffman, 2006; Holmer et al., 2009a).

Although beef enhancement can increase palatability, these products may be at a higher risk for adulteration via pathogen translocation (Luchansky, Phebus, Thippareddi, & Call, 2008; Sporing, 1999). In the early 2000s, the United States Department of Agriculture (USDA)—Food Safety and Inspection Service (FSIS) linked three outbreaks of *Escherichia coli* O157:H7 to mechanically tenderized beef cuts (FSIS, 2003, 2004; Laine et al., 2005). In response to these outbreaks, in 2005 FSIS mandated that facilities producing whole-muscle, non-intact beef products had to reassess their HACCP plans to account for possible adulteration (FSIS, 2005).

A two-step process of applying a surface decontaminant followed by mechanical tenderization has been studied and proven to be effective for several antimicrobials as processing aids (Echeverry et al., 2009; Heller et al., 2007). However, for enhanced products a one-step process that includes the antimicrobial in the brine solution could save time and resources. Sodium lactate and blends of sodium lactate with sodium diacetate added to enhancement solutions with sodium chloride and phosphate have been found to be effective against *E. coli* K12 in beef (Paulson, Wicklund, Rojas, & Brewer, 2007; Wicklund, Paulson, Rojas & Brewer, 2006, 2007). One caveat to including antimicrobials in enhancement solutions is that they must be labeled on the ingredient statement. Both consumers and processors are increasingly interested in additives with clean label applications, such as buffered vinegar, where the active ingredient is acetic acid. Ponrajan et al. (2011) found that sodium citrate plus sodium diacetate or buffered vinegar can have positive antimicrobial effects against *E. coli* O157:H7 when included in beef enhancement solutions.

As new ingredients are incorporated into meat products as antimicrobials (Ponrajan et al., 2011), it is important to evaluate their impact on color, shelf-life, quality, and sensory characteristics. Therefore, the objective of this research was to evaluate the implications of including sodium citrate plus sodium diacetate or buffered vinegar in common

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beef enhancement solutions on top sirloin steak shelf-life, color, sensory, and tenderness characteristics.

2. Materials and methods

2.1. Meat procurement and enhancement

Sixty Institutional Meat Purchase Specifications 184B beef top sirloins (*gluteus medius*) from market cows were obtained (FPL Foods LLC, Augusta, GA, USA) 3 d post harvest and transported (0 ± 2 °C) to the University of Georgia Meat Science Technology Center (Athens, GA, USA) and stored in their vacuum packages (0 ± 2 °C) until 7 d postmortem. Prior to enhancing, twenty top sirloins were randomly assigned to one of three treatments including: 1) 0.5% sodium chloride and 0.4% sodium tripolyphosphate as the control (CNT); 2) CNT with a 1% solution of 80% sodium citrate plus 20% sodium diacetate (SC + D) (IONAL LC, WTI Inc., Jefferson, GA, USA); or 3) CNT with 2% buffered vinegar (VIN) (MOstatin V, WTI Inc.) in the final product. The concentrations for SC + D and VIN were determined by the allowable limits according the material safety data sheet and consultation with the product manufacturer. A recirculating multineedle injector with 21 needles (4 mm) operating at 41 strokes per min and 130 kPa (Injectamatic PI21, Koch Equipment LLC, Kansas City, MO, USA) was calibrated to deliver a 10% solution pickup. Twelve hours prior to muscle enhancement, all treatments were thoroughly mixed for 1 h (Custom Polar Brine Mixer, Wolf-Tec, Inc., Kingston, NY, USA). Immediately prior to injection, the enhancement solutions were remixed to ensure homogeneity. Before and after injection, data was collected including muscle weight (Panther Model, Mettler-Toledo Inc., Worthington, OH, USA) and muscle and enhancement solution pH (pH 11 series pH/mV/°C meter, Oakton Instruments, Vernon Hills, IL, USA with pH probe EW-05998-20 GG9, Cole-Parmer Instrument Company, Vernon Hills, IL, USA). Objective CIE L*, a*, b* color was collected at illuminant D65 with a 2° viewing angle and 50-mm measuring area (CR-310 Chroma meter, Minolta Corporation, Osaka, Japan) calibrated to white and black tiles. pH and objective color were measured after a slice was removed from the lean face to expose fresh lean. After enhancement, the top sirloins were 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) using a Type 800 (Henkelman BV, Hertogenbosch, the Netherlands) vacuum packager and stored (0 ± 2 °C) in the dark for 10 d to simulate transportation and storage time (Voges et al., 2007). All equipment was thoroughly cleaned between each treatment to prevent cross contamination of enhancement solutions.

2.2. Sample preparation

After 10 d of cold storage, the top sirloins were removed from the vacuum bags and allowed to drip for 10 min to remove excess purge. The muscles were weighed, and pH and objective color were measured at approximately the same location stated in Section 2.1. Ten top sirloins from each treatment were randomly selected and cut into 2.54 cm thick steaks. Four steaks from each top sirloin were randomly selected, weighed, and placed on absorbent pads (Dri-Loc AC-40, Cryovac Sealed Air Corporation) in trays (Cryovac thermoformed polystyrene processor trays, Cryovac Sealed Air Corporation) and wrapped with an oxygen permeable polyvinylchloride overwrap (O_2 transmission = 23,250 mL/m^2/24 h, 72 gage; Pro Pack Group, Oakland, NJ, USA).

The remaining 10 top sirloins from each treatment were fabricated into steaks 2.54 cm thick. Four steaks from each top sirloin were re-vacuum packaged and randomly assigned to 0, 7, 14, or 21 d (d 10, 17, 24, or 31 post enhancement) of additional dark storage (0 ± 2 °C) to simulate the time samples could remain in a food service cold chain (Voges et al., 2007). At the end of the respective aging periods, all samples were frozen (−28 ± 2 °C) for Warner–Bratzler shear force (WBS) determination. A fifth steak from each top sirloin was immediately vacuum packaged and frozen (−28 ± 2 °C; d 10 post enhancement) for sensory analysis.

2.3. Warner–Bratzler shear force

The frozen WBS steaks were allowed to thaw (4 ± 1 °C) for 18 h. Steaks were cooked on broilers (model 450N Open-Hearth Broiler, Farberware, Bronx, NY, USA) preheated for 20 min, to an internal temperature of 71 °C and turned once when their internal temperature reached 35 °C (AMSA, 1995). Internal temperature was monitored by a Digi-Sense 12-channel scanning thermometer (Model 9200-00, Cole-Palmer, Vernon Hills, IL, USA) with copper–constantan thermocouples (Omega Engineering, Stamford, CT, USA) inserted into the geometric center of each steak. After cooking, the steaks were allowed to cool to room temperature (21 °C). After 4 h, six 1.27 cm cores from the *gluteus medius* of each steak were removed parallel to the longitudinal orientation of the muscle fibers using a hand held coring device. Cores were sheared once perpendicular to the longitudinal orientation of the muscle fibers with a Universal Testing Machine (Instron Dual Column Model 3365, Instron Corp., Norwood, MA, USA) equipped with a Warner–Bratzler shear head with a 51 kgf load cell with a crosshead speed of 25 cm/min. The peak shear force (kgf) for each core was recorded (Bluehill software, Instron Corp.) and analyzed to obtain an average value for each steak.

2.4. Sensory analysis

Top sirloin steaks for sensory analysis were thawed and cooked similar to WBS steaks described in Section 2.3. After the steaks were cooked to an internal temperature of 71 °C, they were served in warmed yogurt makers (Euro Cuisine, Inc., Los Angeles, CA, USA) to an 8 member trained sensory panel (AMSA, 1995). The sensory panelists evaluated 2 cubes per steak (1.27 cm^3) and evaluated 6 steaks per session, with 2 sessions per day over 1 week. The samples were given so that the panelists received two samples from each treatment in a random order at each session. The loaded yogurt makers were passed through a breadbasket from the sensory kitchen to the sensory analysis room. The sensory analysis room was equipped with negative pressure ventilation and 8 individual booths with red lighting to minimize panelist influence and mask differences in cooked steak color. The panelists evaluated each sample for initial tenderness (8 = extremely tender, 7 = very tender, 6 = moderately tender, 5 = slightly tender, 4 = slightly tough, 3 = moderately tough, 2 = very tough and 1 = extremely tough), sustained tenderness (8 = extremely tender, 7 = very tender, 6 = moderately tender, 5 = slightly tender, 4 = slightly tough, 3 = moderately tough, 2 = very tough and 1 = extremely tough), beef flavor intensity (8 = extremely intense, 7 = very intense, 6 = moderately intense, 5 = slightly intense, 4 = slightly bland, 3 = moderately bland, 2 = very bland and 1 = extremely bland), overall juiciness (8 = extremely juicy, 7 = very juicy, 6 = moderately juicy, 5 = slightly juicy, 4 = slightly dry, 3 = moderately dry, 2 = very dry and 1 = extremely dry), and off-flavor (6 = extreme off-flavor, 5 = very strong off-flavor, 4 = moderate off-flavor, 3 = slight off-flavor, 2 = threshold off-flavor and 1 = none detected).

2.5. Objective and subjective shelf-life color

The packaged top sirloin steaks were placed in cold storage room (4 ± 1 °C) with 24 h luminescence at 960 lux to simulate aerobic display over 7 d. Objective CIE L*, a*, b* was measured on d 0, 1, 3, 5, and 7 as stated in Section 2.1, except the Minolta Chroma meter was calibrated after the white and black calibration tiles were wrapped in the polyvinylchloride overwrap. In addition, hue angle [$\tan^{-1}(b^*/a^*)$] and chroma value [$(a^{*2} + b^{*2})^{0.5}$] were calculated (Hunt et al., 1991). Three objective color readings were recorded for each steak on each day. A 6 member trained color panel also recorded subjective color on d 0, 1, 3, 5, and 7