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Technological characteristics of pre- and post-rigor deboned beef mixtures from Holstein steers and quality attributes of cooked beef sausage

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ABSTRACT

The objective of this study was to determine the effects of deboning time (pre- and post-rigor), processing steps (grinding - GB; salting - SB; batter formulation - BB), and storage time on the quality of raw beef mixtures and vacuum-packaged cooked sausage, produced using a commercial formulation with 0.25% phosphate. The pH was greater in pre-rigor GB and SB than in post-rigor GB and SB ($P < .001$). However, deboning time had no effect on metmyoglobin reducing activity, cooking loss, and color of raw beef mixtures. Protein solubility of pre-rigor beef mixtures (124.26 mg/kg) was greater than that of post-rigor beef (113.93 mg/kg; $P = .071$). TBARS were increased in BB but decreased during vacuum storage of cooked sausage ($P \leq .018$). Except for chewiness and saltiness being 52.9 N-mm and 0.3 points greater in post-rigor sausage ($P = .040$ and 0.054, respectively), texture profile analysis and trained panelists detected no difference in texture between pre- and post-rigor sausage.

1. Introduction

Pre-rigor processing is advantageous in meat processing because it leads to less chill loss (about 1.5% less), drip loss (up to 0.6% less), cooler space (up to 55% less), electricity (up to 50% less), and capital investment. It also allows for quicker turnover of meat, greater product yield, increased labor savings (20% more), and less transportation cost (Claussen et al., 2017). Bowater (2001) estimated that pre-rigor deboning would increase yield by 4% in a beef plant that processes 500 cattle per day for 250 days annually, which in turn would save $3.3 million. Furthermore, pre-rigor processing requires less effort and decreases the number of strain-induced injuries in workers (Adam, 2012; Fung, Kastner, Hunt, Dikeman, & Kropf, 1980; Herbert & Smith, 1980; Van Laack & Smulders, 1989). Although pre-rigor deboning is commonly used in other countries such as Australia and New Zealand, it is less common in the U.S. beef industry because of concerns about training costs, hygiene standards, and the potential for increased toughness due to cold shortening (Keenan, Hayes, Kenny, & Kerry, 2016). Another hurdle to the use of pre-rigor beef is a greater risk of *E. coli* and the required testing of this pathogen in all beef carcasses (Sukumaran et al., 2018; USDA/FSIS, 2018).

Advantages of using pre-rigor meat when making comminuted meat products are a result of greater pH, water-holding capacity (WHC), residual ATP level, protein solubility, and emulsifying capacity (Cheng & Sun, 2008; Claus & Sørheim, 2006; Claussen et al., 2017). Greater WHC leads to decreased cooking loss, an important quality attribute of raw meat used for processed meat products because it impacts yield and profitability and is vital for texture of finished products (Cheng & Sun, 2008; Toscas, Shaw, & Beilken, 1999; Van Oeckel, Warnants, & Boucque, 1999). For example, pre-rigor pork patties had greater protein functionality and retained more fat during cooking because it had greater amount of disassociated actin and myosin than post-rigor patties (Claussen et al., 2017). Similarly, pre-rigor deboned turkey sausage batter had 5% less cooking loss than post-rigor batter (Medellin-Lopez, Sansawat, Strasburg, Marks, & Kang, 2014), which led to greater hardness, gumminess, and chewiness (Lee, Erasmus, Swanson, Hong, & Kang, 2016).

Even though the economic and technological benefits of pre-rigor deboning are well-documented in comminuted pork and poultry products, data are lacking for pre-rigor beef products. Sørheim, Uglem, Lea, Claus, & Egelandsdal (2006) indicated that pre-rigor beef patties had greater pH, less cooking loss, and firmer texture than patties made from post-rigor beef. However, it is important to ascertain the impacts of using pre-rigor beef on quality attributes of premium cooked beef sausage. In sausage production, grinding, salting, and batter formulation are important processing steps because they significantly change

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physical (particle size), chemical (pH, composition, ingredient functionality, etc.), and sensory characteristics (flavor and texture) of raw meat and cooked sausage (Noor, Radhakrishnan, & Hussain, 2016). Hence, the objective of the current study was to determine the effects of deboning time (pre- and post-rigor), three processing steps (grinding, salting, and batter formulation), and storage time on technological characteristics of beef mixtures and quality attributes of cooked beef sausage. Beef trimmings were collected from culled Holstein steers.

2. Materials and methods

2.1. Experimental design

Experimental design and sausage production were detailed by Sukumaran et al. (2018). Briefly, beef trimmings were collected from five 24-month old Holstein steers slaughtered at the federally inspected Mississippi Meat Science and Muscle Biology Laboratory. The left beef sides were designated for pre-rigor treatment; whereas the right sides were used for post-rigor treatment. Lean trimming was collected from the chuck primals; whereas fat trimming was collected from the briskets, chucks, rounds, and plates on the same sides. Lean and fat trimmings were separated but processed similarly according to the designated treatments. For the pre-rigor treatment, the primals were deboned immediately after slaughter, ground to a particle size of 1.27 cm (ground beef – pre-rigor GB), salted (salted beef – pre-rigor SB; 1.5% sodium chloride, w/w) using a paddle mixer, and chilled to 2 °C by mixing with powdered dry ice (15% w/w; Sørheim et al., 2006). The pre-rigor SB was stored at 2 °C in plastic lugs and was processed to sausage batter (pre-rigor BB) on d 6 post-mortem, to be consistent with commercial processing. For post-rigor treatment, beef sides were hung in a 2 °C cooler and deboned on d 4 post-mortem. Post-rigor trimmings were not ground on d 4 but cubed and stored in plastic lugs and then processed to sausage batter on d 6 post-mortem. On the day of sausage production (d 6 post-mortem), post-rigor trimmings were ground to 1.27-cm particle size (post-rigor GB) and salted with 1.5% sodium chloride (w/w) for the purpose of sampling post-rigor SB before being processed into post-rigor BB. Salted ground beef (approximately 22.7 kg of lean and 9.1 kg of fat trimming), both pre- and post-rigor, was processed into sausage batter by grinding the lean and fat trimming separately through a 0.16-cm plate and mixing them with ingredients (beef bratwurst spice mix, water/ice slurry, corn syrup, erythorbate, nitrite, salt, and 0.25% w/w sodium tripolyphosphate). Fat and lean were then blended together in a paddle mixer and ground again through a 0.16-cm plate. No antimicrobial was used in batter formulation. The sausage batter was stuffed into 32-mm synthetic collagen casings and portioned into 15.2-cm links. Equipment used for sausage production and cooking was cleaned with hot water and soap thoroughly between batches of sausage. Sausage was cooked by a generic smoked sausage cycle, including pre-drying, smoking, steaming, and cold shower, to a core temperature of 74 °C. Cooked sausages were chilled for 24 h and five sausage links were packaged in a vacuum bag (B2620 barrier bags; Cryovac, Sealed Air Corporation, Duncan, SC; OTC of 3 to 6 mL per m^2 per 24 h at 4 °C and 0% RH and MVTR of 0.5 to 7.75×10^{-4} to 9.3×10^{-4} g per cm^2 per 24 h at 37.8 °C and 100% RH). Vacuum-packaged sausage was stored 2 °C for 0, 30, 60, 90, and 120 d. The storage times mimicked typical commercial storage, transportation, and end of sale in retail establishments.

2.2. Sample collection

Samples (200 g) were collected in triplicate during grinding, salting, and batter formulation for proximate analysis and color measurement. In addition, 100-g samples were collected from each of these processing steps and from cooked sausage on d 0, 30, 60, 90, and 120 of vacuum storage (casings removed), for subsequent chemical analysis. These samples were frozen in liquid nitrogen, pulverized to a fine powder, and stored at −80 °C until chemical analyses. Cooked sausage links were also collected on d 30, 60, 90, and 120, vacuum-packaged, and stored at −20 °C for descriptive sensory evaluation. Sausage collected on d 30 was also used for instrumental texture analysis. The authors of the current study hypothesized that storage time would not impact sausage texture, but rather sausage aroma and flavor. The sausages were frozen at in vacuum packages until all the samples (30 to 120 d) were collected and the panelists were trained. This was due to logistical limitation of conducting a sensory panel on the same day with other sampling purposes. It was determined that even though freezing and subsequent thawing might affect the sensory attributes of cooked sausages, these effects would be uniform across all the treatments.

2.3. Sample analysis

2.3.1. pH

These data were recorded and published by Sukumaran et al. (2018). However, because pH was relevant to the discussion of technological quality of raw meat and quality attributes of cooked sausage, it will be discussed again here. The pH of GB, SB, and BB was recorded in triplicate by inserting a portable digital FC 2320 digital probe with temperature compensation (Hanna Instruments United States, Inc., Woonsocket, RI) directly into the samples. For cooked sausage, 1 g of pulverized sample was mixed with 10 mL of deionized water and pH was recorded by a temperature-compensation probe (Accumet 13–620-631, Fisher Scientific, Waltham, MA). Both pH meters were calibrated with pH 4, 7, and 10 buffers.

2.3.2. Proximate analysis

Moisture, fat, protein, and collagen composition of GB and BB was quantified using a near-infrared spectrometer (AOAC International, 2018; FoodScan Lab Analyzer model 78,810, FOSS Analytical A/S, Slangerupgade, Denmark). Samples were finely chopped (Oster® 3-Cup Mini Food Chopper, Rye, NY), and placed in a 140-mm plate for NIR analysis.

2.3.3. Cooking loss

Sausage links were weighed before (raw weight) and after cooking (cooked weight), and cooking loss (%) was calculated as the ratio of the difference between raw weight and cooked weight to raw weight, multiplied by 100.

2.3.4. Lean color and percentage of myoglobin forms

Lean color and myoglobin percentages were measured by reflectance spectroscopy (MiniScan EZ 4500 L, Hunter Associates Laboratory, Inc., Reston, VA) with illuminant A, a 10° observer angle, and 2.5-cm aperture size. In addition to L^*, a^*, and b^* values, reflectance spectra of 400 to 700 nm by a 10-nm interval were also recorded to calculate percentages of deoxymyoglobin (DMb), oxymyoglobin (OMb), and metmyoglobin (MMb) as described in the AMSA Meat Color Measurement Guidelines (AMSA, 2012).

2.3.5. Protein solubility

Protein solubility of GB, SB, and BB was determined by extracting the soluble proteins in distilled water and quantification using the Bradford protein assay (Joo, Kauffman, Kim, & Park, 1999). Distilled water was used instead of phosphate buffer to prevent the buffer from confounding with the effects of each processing step on the physical and chemical characteristics of raw beef mixtures. For example, BB had 0.25% phosphate, whereas GB and SB did not. Preliminary trials were conducted to select the suitable medium. A 0.5-g sample was mixed with 10 mL of distilled water, vortexed vigorously for 5 min, centrifuged at 12000 × *g* for 20 min, and the supernatant was used for quantifying proteins. For the protein assay, 10 µL of supernatant was mixed with 300 µL of Coomassie blue reagent (Thermo Scientific™ 23,236, Waltham, MA) in a 96-well plate, incubated for 10 min at room