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Changes in the physiochemical, microbial, and sensory characteristics of fresh pork sausage containing rosemary and green tea extracts during retail display

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ABSTRACT

The effects of adding combinations of rosemary (R: 1500, 2000, 2500 ppm) and green tea (G: 100, 200, 300 ppm) extracts in combination with synthetic antioxidants on the physiochemical, microbial, and sensory characteristics of fresh pork sausage were evaluated. R and G improved ($P < .05$) oxidative stability as evidenced by lower TBARS. R2500 and G300 had fewer PPC than the control at d 7, 14, and 21 of storage. Consumer acceptability scores were greater ($P < .05$) in sausages with R and G when compared to the control, and the majority of the R and G treatments were liked by 98% of the respondents. Treatment combinations of at least R2000 and G200 were described by positive drivers of liking such as spice-complex, ginger, nutmeg, rosemary flavors and aromas and lower scores for descriptors such as rancid, fruity, and off-flavor/odor. This research demonstrates that rosemary and green tea extracts improved the keeping quality of fresh pork sausage under simulated retail display.

1. Introduction

Ground meat products, such as fresh pork sausage, are susceptible to oxidative changes because the comminution process disrupts the muscle membrane system and promotes the autoxidation process by exposing unsaturated fats and proteins to molecular oxygen, oxidative enzymes, heme compounds, and metal prooxidants (Barbut, Josephson, & Maurer, 1985; Papuc, Goran, Predescu, & Nicorescu, 2017). In addition to the comminuted nature of fresh pork sausage, the lack of thermal processing in such products make them prone to spoilage by microbial contamination. These primary mechanisms of quality deterioration limit shelf-life through changes in flavor, texture, and color (Shahidi, Pegg, & Saleemi, 1995).

One of the major strategies employed by manufacturers to reduce oxidation and prevent microbial growth is the use of synthetic food additives with antioxidative and antimicrobial properties including butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tertiary-butylhydroxyquinone (TBHQ), and propyl gallate (PG) (Hazen, 2005). Plant-derived ingredients contain phenolic compounds that are effective antioxidants in a variety of meat and meat products due to their redox properties, which allow them to act as reducing agents, hydrogen donors, and singlet oxygen quenchers in addition to their metal-chelating ability (Kähkönen et al., 1999) and strong antimicrobial activities (Søltoft-Jensen & Hansen, 2005).

Rosemary (*Rosmarinus officinalis L.*) extract's antioxidant properties have predominantly been attributed to the phenolic diterpenes, carnosic acid and carnosol, which terminate the cycle of free-radical chain reactions by hydrogen donation and scavenge reactive oxygen species (Basaga, Tekkaya, & Acikel, 1997). Rosemary extracts (100–1000 ppm) suppress lipid oxidation in beef patties (Sánchez-Escalante, Djenane, Torrescano, Beltrán, & Roncalés, 2001), chicken breakfast sausages (Lee, Williams, Sloan, & Littell, 1997) and surimi gels (Pérez-Mateos, Lanier, & Boyd, 2006). Sebranek, Sewalt, Robbins, and Houser (2005) demonstrated that use of 2500 ppm of a commercial rosemary extract has greater antioxidant capacity when compared to 200 ppm of BHA/BHT when used in refrigerated fresh pork sausage. Lipid oxidation has also been inhibited in pork patties, pork batters and pork sausages through the addition of rosemary extract (Jiang, Zhang, True, Zhou, & Xiong, 2013; Martínez, Cilia, Beltran, & Rocales, 2007; Georgantelis, Ambrosiadis, Katikou, Blekas, & Georgakis, 2007; Hernandez-Hernandez, Ponce-Alquicira, Jaramillo-Flores, & Legarreta, 2009).

The antioxidant activity of green tea (*Camellia sinensis L.*) extract has

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been ascribed to catechin gallates, particularly its main polyphenolic constituent, epigallocatechin gallate (EGCG) (Rice-Evans, 1995). The mechanism for their antioxidant efficacy is attributed to chelating free iron ions which are released from hemoproteins in meat during storage or processing (Tang, Kerry, Sheehan, Buckley, & Morrissey, 2001). In addition, the ability of the catechins to trap superoxide, hydroxyl, and peroxyl radicals and to end free-radical chain reactions slows lipid oxidation (Vuong, Stathopoulos, Nguyen, Golding, & Roach, 2011). Green tea extract has also been used to slow oxidation in minced beef patties (Tang et al., 2006), goat meat (Rababah et al., 2011), fresh pork sausages and pork chops (Martínez, Cilla, Beltrán, & Roncalés, 2006a; Jongberg, Torngren, & Skibsted, 2018). Mitsumoto, O'Grady, Kerry, and Buckley (2005) reported that the addition of tea catechins at 200 or 400 ppm suppressed lipid oxidation in raw meat patties after 7 d of storage at 4 °C. Minimal research has been reported on using a combination of rosemary and green tea extracts with synthetic antioxidants in fresh pork sausages under retail display conditions. Therefore, the objective of this study was to investigate the effects of adding varying combinations of rosemary and green tea extracts with synthetic antioxidants on the physicochemical, microbial, and sensory characteristics of fresh pork sausage during simulated retail display.

2. Materials and methods

2.1. Materials

Commercial rosemary- (*Rosmarinus officinalis L.*) (R) and green tea (*Camellia sinensis L.*) (G) extracts (FORTIUM® Brand) were supplied by Kemin Food Technologies Inc. (Des Moines, IA, USA). The following reagents were purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA): 2-thiobarbituric acid (TBA), sodium dodecyl sulfate (SDS), sodium hydroxide, propyl gallate, ethylenediamine-tetraacetic acid (EDTA), 1-butanol, pyridine, and 1,1,3,3-tetramethoxypropane (TMP). Glacial acetic acid was obtained from Fisher Scientific (Pittsburgh, PA, USA) while ethanol was procured from Decon Laboratories, Inc. (King of Prussia, PA, USA).

2.2. Fresh pork sausage formulation and processing

2.2.1. Preparation of fresh pork sausage

Coarsely ground whole-hog pre-rigor meat (30–45 min postmortem, containing 1.5% salt to delay rigor onset) was made into sausage within 7 d of slaughter with a target of 27.5 ± 1% fat and 55% moisture. Meat temperature was 1 ± 1°C (Model 00645 W2; Acu-Rite, Schaumburg, IL) upon arrival and was stored in a walk-in cooler (3 ± 1 °C) for 24 h to facilitate blending. The addition of synthetic antioxidants in all treatments included a proprietary combination of butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and propyl gallate (PG) at approximately 0.02% based on fat composition, which is within the legal limits described by USDA (9 C.F.R. §319.141, 9 C.F.R. §424.21) (United States Code of Federal Regulations, 2015). Ten 36.3-kg batches of fresh pork sausage were formulated and randomly assigned to contain one of the following treatment combinations: Control (synthetic antioxidants only); 1500 ppm rosemary (R) + 100 ppm green tea (G), 1500R + 100G; 1500 ppm R + 200 ppm G (1500R + 200G); 1500R + 300G; 2000R + 100G; 2000R + 200G; 2000R + 300G; 2500R + 100G; 2500R + 200G; 2500R + 300G. A total of 30 (10 treatments × 3 replications) 36.3-kg batches of fresh pork sausage were manufactured in the entire study.

A proprietary combination of a spice blend, corn syrup solids, chilled water and synthetic antioxidants were added with each treatment combination to a batch of prerigor meat and blended for 3 min in a commercial paddle mixer (Model 150, Butcher Boy Limited, Ayshire, Scotland, UK). The natural plant extracts were added dry and dispersed in the spice blend prior to addition to the meat block. The blended meat was stored in a walk-in cooler (1 ± 1°C) for 48 h prior to grinding (Model 80,055 Mixer-Grinder, Hollymatic Co., Countryside, IL) through a 4-mm grinder plate. Aliquots of ground meat were collected and analyzed for fat, moisture, and protein contents (Method 2007.04; AOAC, 2007) using a FOSS FoodScan™ Meat Analyser Near-Infrared (NIR) Spectrophotometer (Model 78810; Foss Co., Hillerød, Denmark) prior to stuffing. Fat, protein, and moisture content ranged from 26.9 to 28.1%, 13.3 to 13.9%, and 52.3 to 53.4%, respectively. After grinding, the meat was vacuum stuffed (Model RS1040C; Risco Vacuum Stuffer, Thiene, Italy) into natural hog casings (Model 10,003, 32/35 mm; Wolfson Casing Corporation, Mount Vernon, NY, USA). Natural casings were tenderized (proprietary procedure), washed with water to eliminate salt, acid-treated and kept in warm water (40 ± 1°C) prior to use. The microbial counts of the untreated and treated casings were enumerated using 3 M™ Petrifilm™ Aerobic Count Plates (3 M™ Global Headquarters, St. Paul, MN, USA). Untreated casings contained 3.3 to 4.1 log cfu/g and treated casings contained between 1.4 and 2.6 log cfu/g. Fresh pork sausages were hand-linked to a 12.7 ± 1-cm length with a 34 ± 1-mm diameter.

2.2.2. Packaging and storage

Fresh pork sausages (5 links per tray) were packaged in polystyrene trays (20S Yellow Tray; Cascades Plastics Inc., Warrenton, MO, USA), overwrapped with PVC stretch film (O_2 Transmission Rate (OTR) = 780 $cm^3/100\ in^2$/day, Moisture Vapor Transmission Rate (MVTR) = 14 g/100in^2/day, Premium-LT 80718; LINPAC Packaging-Filmco Inc., Aurora, OH, USA), heat-sealed, and immediately stored in an air-blast freezer overnight. The packaged sausages were stored in a walk-in freezer (Model TK-3476-WF-L, K Thermo-Kool, MidSouth Industries Inc., Laurel, MS, USA) and held for 3 mo in the dark at −20 °C prior to refrigerated retail display.

After 3 mo of frozen storage (−20 °C), fresh pork sausages (16–20 trays per treatment) were randomly arranged at 3 ± 1 °C in a walk-in cooler (Model TK-3476-WF-L; K Thermo-Kool, Mid -South Industries Inc., Laurel, MS, USA) where all treatments were exposed to continuous fluorescent lighting (Cool White 34 W; Sylvania Supersaver Ecologic, Danvers, MA, USA) for 21 d. The light exposure level was positioned so that it provided approximately 800 lx at the package surface to simulate retail conditions in a multideck open display cabinet.

Five packages from each treatment were randomly chosen after 0, 7, 14, and 21 d of retail display and subjected to instrumental color, lipid oxidation, and sensory descriptive analysis. Consumer acceptability was determined after 8 d of retail display. Samples for psychrotrophic plate counts (PPC), pH, and proximate analysis were vacuum packaged in 3-mil standard barrier vacuum pouches (Prime Source® 75001826, 0.75 gauge nylon/2.25 gauge polyethylene, OTR = 0.6 $cm^3/100\ m^2$/day at 0 °C, MVTR = 0.6 g/100m^2/day at 38°C, and 100% relative humidity; Rebel Butcher Supply Company, Flowood, MS, USA) and frozen (−72 °C) in an ultralow freezer (Model, Lo-Cold Freezer, ScienTemp Corp, Adrian, MI, USA) until subsequent analyses could be conducted.

2.3. Physicochemical analyses

Only the treatment combinations which were selected for consumer acceptability were evaluated for pH, proximate analysis, and psychotrophic plate counts as it was not feasible to analyze all treatments due to time constraints.

2.4. Instrumental color analysis

Instrumental color measurements were obtained for *CIE* (Commission Internationale de l'Éclairage) lightness (L*), redness (+a*), yellowness (+b*), chroma (saturation index) and hue angle (discoloration) using a chroma meter (Model CR-400, Serial No. C8202489; Minolta Camera Co. Ltd., Osaka, Japan) equipped with a 32 mm diameter measurement area, a D_{65} illuminant and a 2° standard observer angle. The chroma meter was standardized with a white