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The impact of packaging system and temperature abuse on the shelf life characteristics of ground beef

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ABSTRACT

New ground beef packaging systems have warranted investigation of their spoilage and quality characteristics. Furthermore, analysis of ground beef spoilage in modified atmosphere packaging (MAP) and stored at abusive temperature is lacking. This research aimed to determine the effect of packaging systems and temperature abuse on the sensory and shelf-life characteristics of ground beef. Ground beef patties were packaged using polyvinyl chloride overwrap (OW), HI-OX MAP (80% O_2, 20% CO_2), LO-OX MAP (30% CO_2, 70% N_2), CO-MAP (0.4% CO, 30% CO_2, 69.6% N_2), or vacuum (VAC) prior to color, odor, biochemical, and microbial analyses over display. CO-MAP exhibited more desirable color and consumer acceptability throughout display. Lean discoloration and odor scores were lower for anaerobic packaging than aerobic packaging. Microbial results mirrored sensory preferences for anaerobic packaging. These results indicate anaerobic packaging extends shelf-life properties and desirable sensory attributes throughout display and temperature abuse.

1. Introduction

Approximately 1.3 billion pounds of ground beef are produced for retail each year — comprising more space in the retail case than any other product (Mize & Kelly, 2004). Mancini and Hunt (2005) found that the appearance of ground beef is the primary standard used by consumers to determine acceptability. Additionally, Carpenter, Cornforth, and Whittier (2001) state that appearance influences consumer purchase decisions. Consequently, all facets of the beef industry have placed significant effort into the development of systems which promote the shelf life and color stability.

Traditional polyvinyl chloride film packaging systems promote the development of oxymyoglobin and the desirable cherry-red color. However, prolonged exposure to oxygen results in the oxidation of oxymyoglobin and formation of metmyoglobin, which manifests itself as discoloration (Mancini & Hunt, 2005). Additionally, consumers are generally unwilling to accept the purplish hue associated with deoxymyoglobin in vacuum packages. Modified atmosphere packaging (MAP) has provided a viable alternative and means for promoting the consumers' desired red color. Additionally, with the advent of case-ready packaging systems, MAP packaged ground beef has increased in its dominance in the retail case (Mize & Kelly, 2004).

Modified atmosphere packages with high levels of oxygen incur the rapid formation of metmyoglobin (Mancini & Hunt, 2005). Additionally, high-oxygen MAP packages are plagued with the development of off-odors and flavors via lipid oxidation (Limbo, Torri, Sinelli, Franzetti, & Casiraghi, 2010). Sørheim, Aune, and Nesbakken (1997) found that the inclusion of low levels of carbon monoxide (CO) in MAP resulted in the formation of carboxymyoglobin, which possesses a stable red color of the same visual spectra as oxymyoglobin. Additionally, Hunt et al. (2004), as well as Brooks et al. (2008) found reduced lipid oxidation and microbial spoilage in CO-MAP packages. Both research teams concluded CO-MAP was a viable solution for the extension of shelf life in ground beef packages.

Modified atmosphere packaging is recognized as one of the most effective methods for the extension of ground beef shelf life (Limbo et al., 2010). However, the advantages attributed to sophisticated packaging systems are sacrificed at unfavorable storage and display temperatures. Not only do increased temperatures accelerate microbial growth and chemical reactions, they also alter the packaging atmosphere, thereby potentially negating any positive benefits of MAP (Limbo et al., 2010). Previous research suggests storage of product at temperatures great than 7 °C can result in growth of pathogenic and spoilage microorganisms (Gill & Reichel, 1989; Shaw and Nicole, 1969; Seideman & Durland, 1983). Furthermore, Koutsoumanis, Stamatiou, Skandamis, and Nychas (2006) found approximately 30% of product in South European countries was displayed at temperature at or above 10 °C, resulting in considerable loss of shelf life while Giannakourou, Koutsoumanis, Nychas, and Taoukis (2001), found that temperatures greater than 10 °C are not uncommon during transportation, storage, or retail display.

James and Bailey (1990) deemed retail display as the weakest link in the commercial cold chain. While MAP has proven to effectively

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improve shelf life at acceptable temperatures, little research has investigated its efficacy at unsuitable temperatures that can be common during display. Therefore, the objective of this study was to determine the effect of various packaging systems and temperature abuse on the sensory and shelf-life characteristics of ground beef.

2. Materials and methods

2.1. Preparation of ground beef

Coarsely ground beef (81:19, lean: fat) packaged in chubs was obtained from a commercial processing facility and transported to the Gordon W. Davis Meat Science Laboratory at Texas Tech University (Lubbock, TX) for preparation and packaging to simulate retail conditions. The coarsely ground beef was placed in a mixer (model A-80, Koch Supplies, Inc., Kansas City, MO) and blended prior fine grinding using a 3.2-mm grind plate (model 346, Biro Manufacturing Company, Marblehead, OH) for each packaging treatment. Finely ground beef was then transferred to a patty forming machine (Model 54, Hollymatic Corp., LaGrange, IL) and portioned into 150 g patties of uniform size and thickness prior to packaging.

2.2. Packaging

Five packaging treatments were evaluated: 1) control: traditional overwrap with polyvinyl chloride (PVC) film, OW; 2) high oxygen modified atmosphere package: 80% O_2, 20% CO_2, HI-OX MAP; 3) low-oxygen modified atmosphere package: 30% CO_2, 70% NO_2, LO-OX MAP; 4) low-oxygen carbon monoxide modified atmosphere package: 0.4% CO, 30% CO_2, 69.6% N_2, CO; 5) vacuum, VAC. Patties assigned to OW packaging were placed on black expanded polystyrene trays (Pactiv Corporation, Lake Forest, IL) and overwrapped with PVC film (MAPAC L, oxygen transmission rate [OTR] = 21, 700 cc^3 of O_2/m^2/24 h; Borden Packaging and Industrial Products, North Andover, MA). Patties assigned to VAC packaging were placed on expanded polystyrene trays inside vacuum package bags (Barrier bag B620, OTR = 30–50 cc^3 O_2/m^2/24 h at 22.8 °C and 1 atm; moisture vapor transmission [MVT] = 0.5–0.6 g water vapor/24 h at 37.8 °C and 100% relative humidity; Sealed Air Inc. — Cryovac Division, Duncan, SC) and sealed at ≥27″ Hg. For MAP treatments, two patties for each treatment were placed in rigid plastic trays (CS 978; OTR = 0.1 cc^3 oxygen/tray/24 h at 22.7 °C and 0% relative humidity; MVT = 2.0 g water vapor/64,516 cm^2/24 h at 37.8 °C and 100% relative humidity; Sealed Air Inc. — Cryovac Division, Duncan, SC), flushed with their targeted atmosphere and sealed with a high-barrier film (LID 1050, OTR < 20 cc^3 O_2/m^2/24 h at 4.4 °C and 100% relative humidity; Sealed Air Inc. — Cryovac Division, Duncan, SC) using a tray sealing machine (model CV/VG-S, Semi-Automatic 320 by 500, G. Mondini, Brescia, Italy). Gas mixtures were achieved using a gas mixer (Checkmate 9900, PBI Dansensor, Glen Rock, NJ) or with certified, pre-mixed cylinders of compressed gases (Airgas, Inc., Lubbock, TX). The modified atmospheres were validated by testing sample packages at the beginning and end of each treatment using a head-space analyzer (Pac Check 333, Mocon, Minneapolis, MN). Packaging for the trial proceeded if the test package was within ±0.5% of the targeted oxygen, nitrogen, and CO_2 levels; and a CO level of 0.4% was measured in CO treatment packages with less than 0.5% residual oxygen.

2.3. Storage and temperature abuse of ground beef patties

On the date of packaging (d 0), HI-OX MAP, LO-OX MAP, CO-MAP and VAC packaged beef patties were placed in the dark for storage without light at 0 to 2 °C for 5 d. Ground beef intended for traditional OW packaging was stored in chubs during dark storage. After 5 d of dark storage, patties were produced from the chub-packaged ground beef as previously described and packaged using PVC overwrap prior to temperature abuse with the other packaging treatments. Following dark storage, all packages were temperature abused at 10 °C during lighted retail display.

To simulate abuse, packages were placed in multi-deck (Model M3, Hussman Corp., Bridgeton, MO) and coffin-style (Model M1, Hussman, Bridgeton, MO) retail cases under continuous fluorescent lighting for 5 d (d 5 through d 10 post-packaging) at 10 °C (multi-deck: 2515 lx; coffin-style: 2140 lx) using high-output bulbs with a color temperature rating of 3500° K and a color rendering index of 70. Following temperature abuse, packages were placed in separate multi-deck and coffin-style cases with similar lighting for an additional 10 d (d 10 through 20 post-packaging) at 0 to 2 °C. Packaging treatments were balanced across case type and packages were rotated daily from side to side and front to back.

2.4. Color and odor sensory analysis

Beef patties were evaluated at specified intervals (d 0, 5, 6, 7, 8, 9, 10, 15, and 20) for changes in color and odor. Both trained (n = 6 to 8 panelists/d) and untrained consumer (n = 39 to 42 panelists/d) panelists were used to detect differences in color and odor during display among samples displayed at simulated retail conditions. Trained panelists were trained in multiple session using representative samples prior to the start of the project. Trained panelists evaluated the color of ground beef patties using a five-point, verbally anchored scale (1 = very bright red, 2 = bright red, 3 = slightly dark red or brown, 4 = moderately dark red or brown, and 5 = very dark red or brown) and surface discoloration (1 = no discoloration, 2 = slight discoloration; 1 to 10%, 3 = small discoloration; 11 to 20%, 4 = moderately discoloration; 21to 60%, and 5 = severe discoloration; 61 to 100%) according to color guidelines set forth by the American Meat Science Association (AMSA, 2012). Consumer panelists were recruited from the surrounding area and compensated for participation in the study. Panelists were asked to determine if the ground beef patties had "good" color (1 = very strongly agree, 2 = strongly agree, 3 = agree, 4 = neutral, 5 = disagree, 6 = strongly disagree, and 7 = very strongly disagree) and how likely they would be to purchase (1 = definitely would purchase, 2 = probably would purchase, 3 = neutral, 4 = probably would not purchase, and 5 = definitely would not purchase) the package based on ground beef color.

Odor panels were conducted on packages removed from the case at each sampling interval. Odor samples were presented to trained and consumer panelists under red lighting. Trained panelists were asked to determine if an off-odor was present (1 = no off-odor, 2 = slight off-odor, 3 = small off-odor, 4 = moderate off-odor, and 5 = extreme off odor). Consumer panels were conducted using four panels per sampling interval (d) consisting of 10 to 11 panelists per panel. No panelists were allowed to participate more than once. Each consumer evaluated at least two samples from each treatment. Consumer panelists were asked if the meat in the packaged smells "fresh" (1 = very strongly agree, 2 = strongly agree, 3 = agree, 4 = neutral, 5 = disagree, 6 = strongly disagree, and 7 = very strongly disagree) and how likely they would be to consume the meat based upon the odor (1 = definitely would consume, 2 = probably would consume, 3 = neutral, 4 = probably would not consume, and 5 = definitely would not consume).

2.5. Instrumental color measurement

Objective color of the beef patties was measured at two separate locations on the surface of the patty immediately after removal from the package using a portable spectrophotometer (Hunter Miniscan XE Plus, Hunter Laboratories, Reston, VA) with illuminant D_{65} for CIE L^*, a^*b^* and a 10° standard observer angle and a 2.54 cm aperture (CIE (Commission Internationale de l'eclairage), 1978). Instrument calibration was completed before use according to the manufacturer's