IMPACT OF LOW-DOSE IRRADIATION ON THE QUALITY AND PALATABILITY ATTRIBUTES OF BEEF SUBPRIMALS

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Abstract - This study was conducted to evaluate the impact of low-dose irradiation on beef quality and sensory attributes. Paired subprimals were randomly assigned to treated (irradiated with a surface dose of 1 to 1.5 kGy) and control (non-irradiated) groups. Following treatment, subprimals were fabricated into thirds and randomly assigned to one of three aging days (0, 14, or 21). After the aging period, subprimal pieces were cut into 2.54-cm thick steaks, and the resulting trimmings were ground to produce 0.113 kg patties. Steaks and patties were randomly assigned to one of three shelf-life days (0, 2 or 4). During retail display, L*, a*, and b* measurements were taken for raw and cooked steak and patty color. Steaks and patties from all treatment groups were evaluated by a trained sensory panel and used for thiobarbituric acid reactive substances (TBARS) analysis. Differences in raw steak and patty color were seen. No differences were evident between cooked steak samples; however, cooked patty color differences were observed. Further, numerous palatability attributes were impacted by treatment and differences in TBARS values were seen. These results suggest that if chilled subprimals or carcasses were treated with low-dose e-beam irradiation, quality and palatability characteristics could be negatively impacted.

I. INTRODUCTION

The meat industry is constantly searching for microbial interventions or processing aids to help reduce pathogens, thereby reducing the probability of a foodborne disease outbreak and subsequent economic losses associated with such outbreaks. Although food has been safely irradiated in the United States for more than thirty years, there is limited application of irradiation to fresh beef. Research has been conducted to assure consumers that the use of food irradiation, according to governmental regulations, is safe and does not increase human exposure to radiation. Energy used in this process is not strong enough to cause food to become radioactive [1].

Many beef quality and sensory attributes might be altered when using low-dose irradiation. In the event that the use of low-dose irradiation is used as a processing aid, more information is needed to allow the beef industry to better understand the consequences associated with low-dose irradiation. The objectives of this study were to determine the impact of low-dose carcass irradiation on the quality characteristics of beef subprimals and trimmings and to determine the impact of low-dose irradiation on palatability characteristics of steaks and ground beef produced from treated subprimals and trimmings.

II. MATERIALS AND METHODS

A. Product selection

Beef inside rounds (*n* = 10), bottom round flats (*n* = 10), and knuckles (*n* = 18) were collected, in pairs, from a commercial meat packing facility. Subprimals then were shipped to Texas A&M University (College Station, Texas) and stored for two days under refrigerated conditions (2-4 °C).

B. Treatment design

Paired subprimals were randomly assigned to either the control (non-irradiated) or treatment (irradiated) group. The treatment group was subjected to low-dose irradiation at the National Center for Electron Beam Research at Texas A&M University (College Station, Texas). During the irradiation process, three Kodak BioMax alanine dosimeter strips were placed on the surface of each subprimal.

C. Subprimal fabrication

All subprimals (control and treated) were fabricated into three equal parts and randomly assigned to an aging day (0, 14, or 21). The subprimal pieces assigned to either 14 or 21 days were stored vacuum packaged under refrigerated conditions (2-4 °C). Following the designated aging times, the subprimal pieces were trimmed of all external fat, trimmings were produced by removing approximately 1.27 cm of exposed lean, and 2.54 cm steaks were produced. After the appropriate numbers of steaks were cut, the remaining lean portion was combined with the lean trim. The trimmings were coarse ground through a 2.54 cm plate, hand mixed, fine ground through a 0.3175 cm plate, hand mixed, and formed into 0.113 kg ground beef patties. All steaks and patties were placed in foam trays with PVC overwrap. Following packaging, steaks and patties were randomly assigned to a shelf-life group (0, 2, or 4 d), and placed under continuous fluorescent lighting to simulate retail display.

D. Trained sensory panel

Following storage, steaks and patties were evaluated for sensory and shelf-life characteristics. Descriptive sensory evaluation was conducted at the Texas A&M University sensory testing facility using an expert, trained meat descriptive-attribute panel. For sensory determinations, steaks were cooked to an internal temperature of 70 °C and patties were cooked to an internal temperature of 75 °C on a Hamilton Beach Portafolio Indoor/Outdoor Grill (Hamilton Beach/Proctor-Silex, Inc., Southern Pines, NC). Internal temperatures were monitored by a copper-constantan thermocouple (Omega Engineering, Stanford, CT) inserted into the geometric center of each steak or patty. Once the internal temperature reached 35 °C for steaks and 37 °C for patties, they were flipped and cooked until the final internal temperature was reached. Following cooking, steaks were cut into 1.27 cm cubes and patties were cut into 1/8 patty wedges and served warm (within 5 minutes post-cooking) to each of five trained meat descriptive attribute sensory panelists. The panel was trained as defined by American Meat Science Association [2] and Meilgaard, Civille and Carr [3]. Flavor, basic taste, mouthfeel, after-taste, and texture attributes were determined during ballot development sessions. After attributes for the ballot were defined, training sessions were conducted. Following training, the study was initiated after panelists could consistently and accurately identify sensory attributes [2]. Each panelist was seated in individual booths equipped with red theater gel lights. Samples were served in a random order and identified using three-digit codes. Unsalted saltine crackers, fat-free ricotta cheese, and double distilled, deionized water were served to the panelists between samples to cleanse their palate. The panelists evaluated each sample using a 16-point universal scale with 0 = none and 15 = extremely intense for attributes defined during the ballot development sessions [3]. Two sessions were conducted with eight samples evaluated per session where samples were represented across treatments.

E. Color analyses

During retail refrigerated storage, color measurements were taken on PVC-packaged steaks and patties on days 0, 2, and 4. After steaks and patties were cooked for sensory analysis, cooked color was assessed. Color was measured using a Minolta Colorimeter (CR-300, Minolta Co., Ramsey, NJ) which was calibrated daily to insure consistency among days. For raw measurements, three different readings were randomly taken from the surface of each patty and steak. For cooked color analysis, three color measurements were taken from the internal portion of each steak and patty by selecting three random cubes and wedges from each steak and patty, respectively.

F. Thiobarbituric acid reactive substances (TBARS)

Lipid oxidation was evaluated using a modified TBA (2-thiobarbituric acid) method defined by Wang, Pace, Dessai, Bovell-Benjamin and Phillips [4]. Standards were produced by combining different concentrations (0, 2, 4, 6, 8, 10, 20, and 30 mg/kg) of tetraethoxypropane (TEP) solution and trichloroacetic acid (TCA) extraction solution. After the standards were made, samples were prepared for extraction. Samples were minced, weighed, 5 g of each sample was placed in a 50 mL centrifuge tube, and 15 mL TCA extraction solution was added. The samples were homogenized for 20-30 seconds using a Polytron homogenizer (PT 10-35 GT, Kinematica, Bohemia, NY). Following homogenization, tubes were placed in a Jouan cenrtrifuge (C 412, Jouan Inc., Winchester, VA) and centrifuged at 1,500 g for 15 min. The samples were filtered through No. 4 Whatman paper and 125 μL of the resulting extract was loaded in triplicate into a 96-well microplate. After the samples were loaded, 125 μL of TBA solution was dispensed into each well of the microplate using a pipette. The loaded microplate was then incubated for 130 min at 40 °C. After incubation, absorbance was read at 532 nm on a microplate reader (Epoch Microplate Spectrophotometer, BioTek, Winooski, VT).

G. Statistical analysis

Data were analyzed by analysis of variance using SAS PROC GLM (SAS Institute, Cary, NC) with an α of $P < 0.05$. The model included main effects of treatment, subprimal, age day, and shelf-life day. Two-, three-, and four-way interactions were included in the full model. If the interactions were not significant ($P > 0.05$), they were pooled into the error term and the final model was calculated. The p-diff function at $P < 0.05$ was used to separate least squares means when significant differences occurred.

III. RESULTS AND DISCUSSION

A. Raw L, a*, b* color space values*

Raw color differences were seen between treated and control samples on day 0 for all subprimals, but few differences were noted when comparing days 2 and 4. For bottom round steaks, L* values observed on aging days 14 and 21 were higher ($P < 0.05$) than those values recorded on day 0. Conversely, the opposite trend was noted for top round steaks, with day 0 L* values being higher ($P < 0.05$) than those values obtained on days 14 and 21. L* values for knuckle steaks were higher ($P < 0.05$) on day 21 when compared to days 0 and 14. For all subprimals, no clear trend was seen for a* and b* values across aging days.

For patties, raw color trends over aging days differed slightly from trends noted for steaks derived from the same subprimals. Bottom round patties presented higher ($P < 0.05$) L* values when comparing day 0 to days 14 and 21. In general, L* values increased over the aging period for patties from top round subprimals. L* values for knuckle patties significantly increased ($P < 0.05$) with each aging day. No consistent trends were noted for a* and b* values across aging days for all three subprimals.

B. Cooked L, a*, b* color space values*

Cooked steak color differences were not observed for any of the main effects or when considering interactions. The same held true when analyzing L* values for patties derived from top rounds and knuckles. However, bottom round L* values increased significantly ($P < 0.05$) when comparing aging day 0 to 21.

C. TBARS

Differences in TBA values were seen, but were too erratic to attribute to a certain variable. When comparing means between irradiated and non-irradiated cuts, it is apparent that some differences do exist. Overall, the TBA values were lower for steaks in comparison to their corresponding patties. Additionally, as the age day increased, the TBA values elevated. Although not consistent, some irradiated products produced elevated TBA values in comparison to their untreated counterparts.

TBA values generally increased between shelf day two and shelf day four. Additionally, the patty TBA values were higher than their steak counterparts. This would be expected due to the added fat component of the ground beef. Also, the surface area of the lean and fat would increase with the grinding process and would allow for a greater amount of oxygen to interact with the product.

D. Trained sensory panel

The majority of significant differences in trained panel ratings, across study main effects, were seen in bottom round steaks. Overall sweet, sour milk, juiciness, muscle fiber tenderness, bloody, and umami attributes were lower ($P < 0.05$) for treated steaks than control. However, treated steaks also obtained higher ($P < 0.05$) panelist ratings for bitter and cardboard, than control steaks. When comparing aging days for bottom round steaks, panelist ratings for sour milk, sour, bitter, cardboard, liver, and putrid increased ($P < 0.05$) as aging day increased. Similar trends were seen when comparing shelf-life days for bottom round steaks. Top round steaks, when derived from treated subprimals, had lower ($P < 0.05$) ratings for fat and juiciness attributes while receiving a higher ($P = 0.0352$) cardboard rating when compared to control steaks from the same subprimal type. Compared to control, knuckle steaks subjected to treatment received lower ($P < 0.05$) scores from panelists for juiciness, muscle fiber tenderness, overall tenderness, and connective tissue amount.

Ground beef patties originating from treated subprimals received higher ($P < 0.05$) ratings for cardboard, sweet, and hardness, while receiving lower ($P < 0.05$) scores for beefy, brown, bloody, fat, sour milk, sour, and juiciness attributes. Further, significant ($P < 0.05$) score decreases were seen when comparing aging days, with beefy, brown, fat, umami, overall sweet, sweet, attributes decreasing as aging day increased. Metallic, cardboard, sour milk, sour, and bitter attributes were continuously rated higher ($P < 0.05$) as aging day increased. These results are expected as sour and cardboard attributes are indicative of spoilage and oxidative rancidity. Again, similar trends were noted when analyzing panel ratings for ground beef patties across shelf-life days.

IV. CONCLUSIONS

If the application of low-dose irradiation were to be both approved and implemented in the U.S. beef industry, these data can be used to develop educational outreach materials to aid in minimizing the impact of low-dose irradiation on beef quality and palatability. This will help ensure the beef industry benefits from the safety aspects of the low-dose irradiation without creating quality problems that could result in economic losses to the industry. Although the impact on food safety has been demonstrated, it is crucial to the industry that we fully understand the quality implications of this technology.

V. ACKNOWLEDGEMENT

This project was funded, in part, by The Beef Checkoff.

VI. REFERENCES

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