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PALATABILITY, COLOR, AND PRODUCT LIFE OF LOW-DOSE IRRADIATED BEEF STEAKS

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KEYWORDS: IRRADIATION, BEEF STEAKS, COLOR, AROMA, FLAVOR

BACKGROUND AND OBJECTIVE

Recent events involving foodborne infections in meat products have increased consumer awareness of possible food contamination with pathogens, especially *Escherichia coli* O157:H7. Of surveyed consumers, 43% were very concerned with food safety (AMIF, 1993). One possible method to increase meat safety is the use of irradiation. The World Health Organization (WHO) stated that no toxicological hazard resulted from consuming food irradiated up to 10 kGy (WHO, 1981). Clavero et al. (1994) and Monk et al. (1994) summarized that 2.5 kGy of gamma irradiation would reduce five major pathogens by 4 to 10 $\log_{10}$ in ground beef. Irradiation has considerable potential for the meat industry when combined with Good Manufacturing Practices. Historically, consumers have rejected irradiation. After educational intervention, the percentage of consumers purchasing irradiated ground beef increased from 51.5% to 70.9% (AMIF, 1993). Little is known about the effects of low dose irradiation on meat quality and thus on consumer acceptance. The objective of this study was to determine flavor, aroma, color, and product life of boneless beef steaks in one of two packaging systems (vacuum and/or PVC film) exposed to three dose levels (0, 2 and 3.5 kGy) of non-radioactive irradiation.

METHODS

Twelve steaks per treatment were cut 2.54 cm thick from boneless beef strip loins (NAMP #180A) obtained from a commercial processor for each of three replications. Steaks were vacuum-packaged in B-630 bags (O_2 transmission of 3-6 cc/m^2/24 hrs at 4.4°C and 0% relative humidity, Cryovac Corporation, Duncan, SC) and either stored frozen at -20 ± 3°C (Study 1) or chilled at 2 ± 1°C (Study 2). Steaks were stored for about 60 hrs, then removed, boxed, and shipped either under dry ice or chilled with arrival within 6 hrs to Iowa State University's (ISU) irradiation facility. After stabilizing product temperature to either -20°C or 2°C overnight, steaks were treated with either 0, 2.0 or 3.5 kGy of non-radioactive X-rays (5 MeV energy level; 12 kW power level). After irradiation, product was shipped back to KSU. Frozen steaks were thawed at 2 ± 1°C overnight. Chilled steaks were stored at -1 ± 1 °C for 14 days. After 14 days, one-half of the chilled steaks were placed onto styrofoam trays, covered with PVC film and allowed to bloom overnight at -1 ± 1°C.

Eight steaks per treatment per replication were broiled to 70°C internally, as measured by T-type thermocouples attached to a Doric temperature recorder (Model 205, Beckman Instruments, Schaumburg, IL). Eighteen texture/flavor attributes: toughness (TOU), juiciness (JUI), meat identity (MID), browned/roasted (BR), bloody (BLD), fat-like (FL), metallic (MET), liver-like (LL), burnt (BT), sweet (SW), sour (SR), bitter (BIT), fat-rancid (FR), fat-animal hair (FAH), fat-chemical (FC), lean-rancid (LR), lean-animal hair (LAH), and lean-chemical (LC) were assessed by five professional flavor profile panelists using a 15-point scale (0 = none to 15 = very intense). Each panelist received one steak per treatment. Off-odors in the package (Study 1) and beef aroma and off-odors after broiling (Study 1 and 2) were evaluated. Cooking loss percentage, Warner-Bratzler Shear (WBS) Force (Universal Testing Machine, Model 4201, Instron Corp., Canton, MA) and cooked internal and external color using Illuminant A CIE L*a*b*, hue angle, saturation index, and a*/b* and 630/580 reflectance ratios (2.5 cm diameter aperture, UltraScan Sphere Spectrocolorimeter, Hunter Associates Laboratory, Inc., Reston, VA) were evaluated.

Two steaks per treatment per replication were tested for purge, pH, total plate count (TPC) using standard procedures (APHA, 1992), and a modified 2-thiobarbituric acid analysis (TBA) (Witte et al., 1970). Two additional steaks were displayed at 2 ± 2°C under 1614 lux light intensity (Philips, 40W Deluxe Warm White) and instrumentally evaluated (5 cm diameter aperture, LabScan 6000 Spectrocolorimeter, Hunter Associates Laboratory, Inc.) as mentioned above at days 0, 7, and 14 for Study 1. For Study 2, PVC-packaged (PVC) steaks were evaluated at 0, 2 and 5 d only, and vacuum-packaged (VP) steaks were evaluated at 0, 2, 5, 7, and 14 d. After final day of display, TBA and TPC were determined. Data were analyzed as a strip-split plot design using the maximum likely-hood mixed model analysis of the Statistical Analysis System (SAS Institute, 1994). Least square means were determined to separate means at $P<0.05$.

RESULTS AND DISCUSSION

Study 1: Dose level did not affect TOU, JUI, MID, BR, BLD, FL, MET, LL, SW, SR, and BIT flavor attributes or beef aroma (Table 1). BT, FR, FAH, FC, LR, LAH, and LC flavor intensities and cooked off-odors did not satisfy the assumption of continuous response, thus differences were difficult to prove. In packaging off-odors were greater in irradiated steaks than in controls (Table 1). However, it was determined that packaging aromatics were being transferred to the sample, and when exposed to air for 2 to 3 min, packaging notes diminished or were not perceptible. Dose level did not influence any instrumental internal or external cooked color values. Raw L*b*, hue angle, saturation index, and a*/b* and reflectance ratios were not influenced by dose. L* and b* values were stable throughout storage. Redness increased from 2 to 3.5 kGy and from 7 to 14 d. Hue angles increased from 0 to 7 d and decreased from 7 to 14 d. Saturation indexes increased from 7 to 14 d. Greater a*/b* ratio was observed at 0 d compared to 7 and 14 d. Opposite results were obtained for reflectance ratios. Cooking loss percentage, pH, WBS, and TBA values were not influenced by dose. Purge percentage was not consistent across dose level. TPC were not different across dose at day 0. At day 14, a 3.05 $\log_{10}$ and 5.02 $\log_{10}$ TPC reduction from controls was observed for 2 and 3.5 kGy irradiated steaks, respectively. Control and 2 kGy TPC values increased from 0 to 14 d, but TPC for 3.5 kGy did not differ between days.

Study 2: Dose level and package type did not affect JUI, FL, MET, SW, and BIT flavor attributes (Table 2). BT, FR, FAH, FC, LR, LAH, and LC attributes and cooked off-odors did not satisfy the assumption of continuous response, thus differences were difficult to prove. Beef aroma decreased in VP compared to PVC steaks, and from 2 to 3.5 kGy (Table 2). TOU, MID, BR, and BLD were not influenced by packaging in either controls or 3.5 kGy steaks, but at 2 kGy, TOU was higher and MID, BR, and BLD were lower in PVC compared to VP steaks. LL and SR were not influenced by packaging in either controls or 2 kGy steaks, but at 3.5 kGy, LL was higher and SR lower in PVC compared to VP steaks. TOU increased from 0 to 2 kGy in PVC steaks, but increased from 2 to 3.5 kGy in VP steaks. MID was lower in PVC controls than in irradiated counterparts, while it increased from 2 to 3.5 kGy in VP samples. BR was not influenced by dose in VP steaks, but 2 kGy PVC steaks were lower than either controls or 3.5 kGy. Within package types, BLD and SR were not influenced by dose. LL was higher in PVC irradiated steaks than controls, and was higher in 2 kGy VP steaks than 0 or 3.5 kGy samples. Dose level did not affect any instrumental internal or external cooked color values. External cooked a*, b* and saturation index were lower in VP steaks than in PVC samples. Dose level did not affect raw L*, b* and a*/b* and reflectance ratios, or VP a*, hue angle and saturation index. VP steaks were stable across storage days for L*a*b*, hue angle, and a*/b* and reflectance ratios. VP saturation indexes were inconsistent across storage days. Raw L* and b* values were higher for PVC steaks at 0, 2, and 5 d compared to VP. Opposite results were obtained for a*/b* and reflectance ratios, except higher reflectance ratios were obtained for 0 d PVC samples. PVC L* values decreased from 0 to 2 d. PVC reflectance ratios and b* values decreased across storage days. PVC a*/b* ratios were stable from 0 to 2 d, but decreased at day 5. Saturation index and a* values decreased across storage days for PVC steaks for all dose levels. PVC hue angles decreased across days for controls, and decreased from 2 to 5 d in irradiated samples. PVC a* values, saturation indexes and hue angles were not influenced by dose at 0 and 2 d. At day 5, a* values and saturation index were lower in control steaks than irradiated samples, and opposite results were obtained for hue angles. Cooking loss percentage, pH and WBS were not affected by dose level or package type (Table 2). Greater purge percentage was observed for VP than for PVC steaks. Day 0 TBA values were higher for PVC steaks than for VP counterparts. Day 5 PVC TBA values were higher than day 0 counterparts and were above threshold level (1.0). Within PVC and VP steaks, TPC were higher for controls than irradiated samples at 0 and 5 d and 0 and 14 d, respectively. No difference was observed in TPC in PVC controls from 0 to 5 d, but TPC increased in irradiated samples across storage days. Day 0 VP 3.5 kGy TPC were not different than day 14 counts, but TPC increased for controls and 2 kGy samples across storage days.

SUMMARY

Irradiation did not influence TOU, JUI, MID, BR, BLD, FL, MET, LL, SW, SR, and BIT flavor notes, beef aroma, internal or external cooked color values, raw L*b*, hue angle, saturation index , a*/b* and reflectance ratios, cooking loss, pH, WBS, and TBA values in frozen steaks. Redness increased from 2 to 3.5 kGy. Irradiation did not influence JUI, FL, MET, SW, and BIT flavor notes, internal or external cooked color values, raw L*b*, a*/b* and reflectance ratios, cooking loss, purge, pH, TBA, and WBS in chilled steaks. Vacuum-packaged steaks were stable across storage days for raw L*a*b*, hue angle, and a*/b* and reflectance ratios. Raw a*, saturation index and hue angle were influenced by dose and storage days in PVC-packaged steaks.

ACKNOWLEGEMENTS

This research was sponsored by the American Meat Institute Foundation. The authors wish to thank Dr. Dennis Olson, Dr. George Milliken, Kevin Chartier, Joanne Eilers, and Dedra Woydziak for their technical and/or statistical assistance.

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Table 1.Mean and standard error (SE) values for flavor/aroma sensory attributes* for frozen boneless beef steaks as affected by dose level.

	Dose (kGy)			
Trait	0	2	3.5	SE
Toughness (TOU)	6.1	6.7	7.0	0.7
Juiciness (JUI)	9.9	9.3	9.4	0.3
Meat Identity (MID)	12.1	12.0	11.8	0.3
Browned/Roasted (BR)	8.6	8.0	8.1	0.2
Bloody (BLD)	4.8	6.2	6.1	0.6
Fat-like (FL)	2.1	2.3	2.3	0.3
Metallic (MET)	3.1	4.0	3.8	0.3
Liver-like (LL)	1.8	2.1	1.2	0.5
Sweet (SW)	0.7	0.5	0.5	0.2
Sour (SR)	1.7	1.9	1.8	0.2
Bitterness (BIT)	1.5	1.8	1.8	0.3
Beef aroma	11.7	11.0	11.2	0.4
Off-odor -In package	0.5^{b}	3.5^{a}	3.5^{a}	0.6
-Cooked	0.0	0.0	0.0	0.0

ab Mean values within the same row bearing different superscript letters are different (P<0.05).
* 15 point scale: 0=none to 15=very intense.

Table 2. Mean and standard error (SE) values for flavor/aroma sensory attributes*, shear force (WBS), cooking loss, purge, and pH for chilled boneless beef steaks as affected by dose level and package type.

	Dose (kGy)				Package		
Trait	0	2	3.5	SE	PVC	VAC	SE
Juiciness (JUI)	8.8	8.6	8.5	0.3	8.6	8.7	0.3
Fat-like (FL)	2.5	2.5	2.6	0.2	2.5	2.6	0.2
Metallic (MET)	3.3	3.7	3.7	0.4	3.5	3.6	0.4
Sweet (SW)	1.0	0.9	0.8	0.2	0.9	0.8	0.2
Bitter (BIT)	1.5	1.7	1.8	0.3	1.7	1.6	0.3
Beef aroma	11.3^{a}	11.5^{a}	10.6^{b}	0.2	10.8^{b}	11.5^{a}	0.1
Off-odors	0.3	0.0	0.5	0.4	0.6	0.0	0.3
WBS (kg)^{c}	3.20	3.25	3.23	0.31	3.29	3.16	0.25
Cooking loss^{d}	22.6	22.1	23.7	1.1	22.8	22.8	1.0
Purge^{d}	0.30	0.42	0.49	0.18	0.00^{b}	0.80^{a}	0.16
pH	5.59	5.64	5.61	0.04	5.63	5.59	0.03

ab Mean values within the same row within dose level or package type bearing different superscript letters are different (P<0.05).
c Warner - Bratzler Shear.
d Expressed as percentage.
* 15 point scale: 0=none to 15=very intense.