Effects of irradiation on properties of cured ham

By: Terry A. Houser and Joseph G. Sebranek

Dept. of Animal Science, 214 Meats Laboratory, Iowa State University, Ames, IA 50011

Abstract

Quality characteristics of cured ham (porcine biceps femoris and semimembranosus), manufactured with the application of ionizing radiation (4.5 kGy) to fresh uncured ham (RAW), fresh cured ham (PB), or cooked cured ham (CKD), were compared with non-irradiated controls (CON) over a 90-day storage period. The research objective was to determine the impact of irradiation processing on nitrite reactions, cured color development, and cured color stability when applied at different steps in the production of cured, ready-to-eat ham. Quality characteristics which were evaluated included; lipid oxidation by modified 2-thiobarbituric acid test (TBA), instrumental color by CIE L* (lightness), a* (redness), b* (yellowness), residual nitrite content, and odor evaluation by trained sensory panel. All irradiated treatments resulted in higher (P<0.05) TBA values compared with the CON treatment. However, no differences (P>0.05) for TBA values were observed between irradiation treatments. The PB treatment resulted in lower (P<0.05) L* values compared with the CON treatment. However, no differences (P>0.05) in L* values were found within any treatment as a result of storage time. No differences (P>0.05) in a* values were observed as a result of irradiation treatment or storage time in any case. All treatments, except for the CKD treatment, exhibited decreasing b* values during the storage time. Residual nitrite content for the CON treatment decreased (P<0.05) from day 7 through day 90, but no difference (P>0.05) in residual nitrite content occurred for any irradiated treatments as a result of storage time. Furthermore, the CKD treatment had lower, although not significantly different (P>0.05) residual nitrite content from day 7 through day 60 compared with all other irradiation treatments and CON treatment. In contrast, both the RAW and PB treatments had higher although not significantly different (P>0.05) residual nitrite contents from day 15 through day 90 compared with the CON treatment. Odor evaluations were carried out by sensory personnel, which were trained to use a line scale with graduations from 0-150 to distinguish intense off-odor (150) from no off-odor (0). Odor evaluation scores were higher (P<0.05) indicating more off-odor for the CKD treatment on day 0 compared with the CON treatment. Furthermore, no differences (P>0.05) were found in odor scores from the RAW or PB treatments compared with the control on any day of storage. This suggests that post-irradiation thermal processing decreased irradiation-induced odors. In addition, no differences (P>0.05) in sensory odor scores were found between any treatments after 30 days of storage suggesting a dissipation of off-odor over time.

Keywords: **Irradiation, nitrite, and color**

Introduction

Increasing concern for contamination of red meat and poultry products with microbial pathogens has prompted the United States Department of Agriculture (USDA) to approve medium dose (1-10 kGy) irradiation for some meat applications. As of February 22, 2000, fresh red meats may be irradiated with doses up to 4.5 kGy and frozen red meats may be irradiated with doses up to 7.0 kGy (USDA 1999). Although thermal processing is the current method of choice for *Listeria monocytogenes* destruction by the meat industry (Wilson 1988), post-heating contamination by this organism has resulted in food-borne illnesses and has been cause of great concern for ready-to-eat (RTE) processed meats (Wang and Muriana 1994). Medium-dose irradiation (1-10 kGy) is not approved for use in processed meats at this time, even though it has been proven to reduce or eliminate pathogens such as *L. monocytogenes* in pre-packaged RTE meats (Gürsel and Gürakan 1997). Furthermore, irradiation treatment of RTE meats coupled with the mandatory Hazard Analysis Critical Control Point (HACCP) program would produce a microbiologically safe product conforming to USDA's zero tolerance policy for *L. monocytogenes*.

Although irradiation can reduce or eliminate microbial pathogens, it may also produce some undesirable quality effects in RTE meats. In previous studies involving cured meat, it has not been possible to clearly define the effect of irradiation on color stability, lipid oxidation and residual nitrite content, particularly during extended storage. Commercial hams, and RTE meats in general, have a shelf life in excess of 60 days. Thus, the objective of this research was to determine the effect of medium-dose irradiation, applied at different points in the manufacturing process, on selected properties of RTE cured ham.

Materials and Methods

Porcine semimembranosus and biceps femoris (ham) muscles were obtained from the Iowa State University Meat Laboratory. The ham was trimmed free of fat with a membrane skinner and cut into three portions then mixed together and randomly assigned by weight to 4 different treatment groups; a control and irradiation at three different points in the ham production process. Ham pieces were injected to a target 125% of initial green weight with curing brine to achieve a concentration of 2.5% sodium chloride, 1.5% sugar, 0.35% sodium phosphate, 550 ppm sodium erythorbate and 200 ppm sodium nitrite. Ham pieces were then macerated and vacuum tumbled continuously for 2 hours. Curing brine was added to the tumbler to achieve the desired 125% pump retention. Ham pieces were vacuum-packaged in cook-in bags, placed into stainless steel ham molds and thermal processed at 79.4°C until an internal ham temperature of 70°C was reached. After thermal processing, hams were chilled for 12 hrs at 2-4°C. The whole hams were removed from molds and sliced to a 5mm thickness, vacuum-packaged, and stored at 2-4°C for 90 days. The experiment was replicated 4 times on 2 separate production days.

Irradiation of ham samples took place at the Iowa State University Meat Laboratory Linear Accelerator Facility (LAF). All treatments except the control received an average absorbed irradiation dose of 4.5 kGy. Irradiation treatments were applied at three separate points in the sequence for the ham production process (Fig. 1). For the Raw treatment, meat was irradiated as a fresh, uncured product just prior to injection. For the PB treatment, meat was irradiated as a cured, uncooked product after injection and maceration but prior to vacuum tumbling. The Cooked treatment was irradiated as a cured, cooked, and sliced product following completion of the manufacturing process. Control samples received no irradiation treatment. All irradiation treatments were applied under anaerobic (vacuum-packaged) conditions.

Control

⇓

Raw ham muscles

⇓ **Irradiation-Raw**

Brine injection

⇓

Maceration

⇓

Vacuum tumble

⇓

Place in cook-in bags

⇓ **Irradiation-PB**

Place into ham molds

⇓

Thermal processing

⇓

Slice and vacuum package

⇓ **Irradiation-Cooked**

Storage up to 90 days

Figure 1. Irradiation Treatments

Color measurements were conducted after 0, 15, 30, 60 and 90 days of storage, using a Hunterlab Labscan colorimeter (Hunter Associated Laboratories Inc., Reston, VA., U.S.A.). Day 0 represented the day that samples were sliced and vacuum-packaged. CIE L* (lightness), a* (redness), and b* (yellowness) were measured for all treatments (Hunt and others 1991).

Lipid oxidation was measured by the modified 2-Thiobarbituric Acid (TBA) test (Zipser and Watts, 1962). TBA values were determined after 0, 15, 30, 60 and 90 days of storage with day 0 representing the day the samples were sliced and vacuum-packaged.

Residual nitrite level was measured in parts per million by the AOAC (1990) method for all treatments following 7, 15, 30, 60 and 90 days of storage. Day 7 was chronologically 7 days after the product was sliced and vacuum-packaged.

Sensory odor evaluations were conducted for all treatments at 0, 15, 30, 60, and 90 days after processing. Each sample was warmed in a water bath while the vacuum package was still intact. Trained panelists (10-12), made up of Iowa State University students and staff, were used for each session. Panelists were trained to distinguish between samples irradiated at 0 and 8 kGy. Unirradiated samples were used (0 kGy) to represent no off-odor and 8 kGy samples were used to represent distinct off-odor for training. Panelists then evaluated samples using a line scale with graduations from 0-150 mm, using 0 to represent no off-odor and 150 to represent intense off-odor. Sample packages were opened by panelists after heating and immediately evaluated for odor.

This experiment was replicated 4 times over a 5-month period. Statistical analysis was performed for all measurements using the Statistical Analysis System (SAS 2000) mixed model procedure. The fixed effects were treatment and storage day. Random effects were replicate within treatment. Least squares means were used to determine level of significance at P<0.05.

Results and Discussion

All irradiated treatments had significantly higher (P<0.05) TBA values than non-irradiated control (Table 1). Although there were significant differences, all TBA values were very low. There were no differences (P>0.05) between the irradiation treatments. The TBA values did not change during storage time within treatment (data not shown).

Table 1. Least squares means for TBA values of irradiated hams by treatment.

Treatment	TBA Value
Control	0.094[a]
Raw	0.12[b]
PB	0.13[b]
Cooked	0.13[b]
S.E.M.	0.0037
S.E. of Differences	0.0052

[a-b] Means within the same column with different superscripts are significantly different (P<0.05).

The effect of irradiation treatment on color as measured by Hunterlab for CIE L* (lightness), a* (redness) and b* (yellowness) of cooked ham slices are reported in Table 2. The control and raw irradiated hams had significantly higher L* values than the fresh cured treatment group. No significant effects of storage time on L* values were found for any treatment in the current study (data not shown). CIE a* values for ham treatments showed no differences (P>0.05) as a result of treatment (Table 2) or storage time (data not shown).

Table 2. Least squares means for CIE L* a* and b* values of irradiated hams by treatment.

Treatment	L*	a*	b*
Control	72.3[a]	16.0	11.1
Raw	72.2[a]	15.0	11.2
PB	70.1[b]	16.3	11.3
Cooked	71.8[ab]	15.3	12.1
S.E.M.	0.46	0.33	0.22
S.E. of Differences	0.66	0.46	0.31

[a-b] Means within the same column with different superscripts are significantly different (P<0.05).

All treatments except the cooked samples exhibited significantly (P<0.05) lower b* values with time over the 90-day storage period becoming less yellow (Table 3). The b* values of the cooked product treatment did not decrease during storage with the exception of day 60, which had lower b* values than day 0. The b* values were not different between day 0 and day 90, and were significantly higher (P<0.05) than all other treatments at 90 days of storage which indicates the product was more yellow than all other treatments. This interaction suggests that irradiation after cooking will stabilize b* values during extended storage.

Table 3. Least squares means for CIE b* values of irradiated hams during storage.

Treatment	Day 0	Day 15	Day 30	Day 60	Day 90
Control	12.0[a]	11.4[ab]	11.3[b]	10.5[c]	10.5[cw]
Raw	12.1[a]	11.5[ab]	11.3[b]	10.6[c]	10.6[cw]
PB	12.1[a]	11.5[ab]	11.2[bc]	10.7[c]	10.8[cw]
Cooked	12.5[a]	12.2[ab]	12.1[ab]	11.7[b]	12.2[abx]

[a-c] Means within the same row with different superscripts are significantly different (P<0.05).
[w-x] Means within the same column with different superscripts are significantly different (P<0.05).
Standard Error of the Mean = 0.25
Standard Error for comparisons within treatment = 0.19
Standard Error for comparisons within day = 0.36

Least squares means for residual nitrite content are listed in Table 4. Irradiation treatments slowed the rate of depletion of residual nitrite during storage compared with the non-irradiated control. The control treatment resulted in lower residual nitrite content on days 60 and after compared with day 7. The raw treatment exhibited no difference in residual nitrite content between day 7 and day 90. The raw cured treatment acted in much the same manner as the raw treatment with no differences in residual nitrite between day 7 and day 90. The cooked treatment showed no significant decrease in residual nitrite content during the storage period.

Table 4. Least squares means for residual nitrite content (mg/kg) of manufactured hams by irradiation treatment and storage period.

Treatment	Day 7	Day 15	Day 30	Day 60	Day 90
Control	14.8[a]	14.1[awx]	12.5[ab]	7.9[bc]	5.3[c]
Raw	13.8[ab]	18.9[aw]	14.2[ab]	11.1[b]	8.8[b]
PB	15.1[ab]	15.9[awx]	15.1[ab]	11.9[ab]	9.9[b]
Cooked	9.3	8.6[x]	9.2	7.7	6.2

[a-c] Means within the same row with different superscripts are significantly different (P<0.05).
[w-x] Means within the same column with different superscripts are significantly different (P<0.05).
Standard Error of the Mean = 1.77
Standard Error for comparisons within treatment = 1.52
Standard Error for comparisons within day = 2.50

Least squares means for sensory odor panel scores are listed in Table 5. The cooked treatment resulted in significantly higher off-odor scores than all other treatments at day-0. However, the cooked treatment was not significantly different (P>0.05) from the other treatments at 30-90 days of storage. It should be noted that the increased off-odor scores did not seem to be the result of rancid odors produced from the oxidation of lipids. Although TBA values were higher for all irradiated treatments, only the cooked treatment had higher off-odor scores compared with the control.

Table 5. Least squares means for sensory off-odor values of manufactured hams by irradiation treatment and storage period.

Treatment	Day 0	Day 15	Day 30	Day 60	Day 90
Control	50.1[w]	46.0[w]	55.8	32.8	36.5
Raw	56.9[w]	44.4[w]	49.4	46.4	41.2
PB	58.2[w]	60.6[wx]	50.2	50.4	43.3
Cooked	83.5[ax]	71.9[abx]	65.5[ab]	52.8[b]	51.3[b]

[a-b] Means within the same row with different superscripts are significantly different (P<0.05).
[w-x] Means within the same column with different superscripts are significantly different (P<0.05).
Standard Error of the Mean = 2.32
Standard Error for comparisons within treatment = 5.45
Standard Error for comparisons within day = 5.88

Conclusions

These results indicate that pork ham may be manufactured with the application of irradiation to raw, uncured ham; cured, uncooked ham or cured cooked ham with minimal changes to lipid stability and cured color stability when irradiated at or below 4.5 kGy. Residual nitrite depletion during storage appeared to be slowed by the application of irradiation. This suggests that free radical production as a result of irradiation processing may reduce the ability of endogenous as well as added reductants to convert nitrite to nitric oxide. Radicals, if produced could also react with nitric oxide. However, it does not seem that this decrease in reducing ability or potential reaction of radicals with nitric oxide has an impact on color stability, either initially or during storage, possibly due to the concentration of nitrite (200 mg/kg) added in the curing process. The application of irradiation to uncured, uncooked ham and cured, uncooked ham does not affect sensory odor panel scores but results in increased off-odor scores for the cured, cooked hams. Thus, irradiation processing has a detrimental affect upon odor acceptability from 0-30 days of storage when doses of 4.5 kGy are used after heat processing is completed.

References

[AOAC] Association of Official Analytical Chemists. 1990. Nitrites in cured meat. In: Official Methods of Analysis. 15th ed. Arlington: AOAC 973.31

Gürsel B, Gürakan GC. 1997. Effects of gamma irradiation on the survival of *Listeria monocytogenes* and on its growth at refrigeration temperature in poultry and red meat. Poultry Sci 76:1661-1664

Hunt MC, Acton JC, Benedict RC, Calkins CR, Cornforth DP, Jeremiah LE, Olson DG, Salm CP, Savell JW, Shivas SD. 1991. Guidelines for meat color evaluation. In: 44th Annual Reciprocal Meat Conference; 1991 June 9-12; Manhattan, KS. Chicago: National Livestock and Meat Board. P 3-17.

[USDA] U.S. Department of Agriculture. 1999. Irradiation of meat food products. Final rule. 9CFR381 & 424 Docket No. 97-076C

Wang C, Muriana PM. 1994. Incidence of *Listeria monocytogenes* in packages of retail franks. J Food Prot 57:382-386

Wilson GD. 1988. Listeria monocytogenes-1988. In: 41st Annual Reciprocal Meat Conference. 1988 June 12-15; Laramie, Wyo. Chicago: National Livestock and Meat Board. P 11-13

Zipser MW, Watts BM. 1962. A modified 2-thiobarbituric acid (TBA) method for the determination of malonaldehyde in cured meats. Food Tech 16:102-104