

Temperature Abuse Affects the Quality of Irradiated Pork Loins

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Summary and Implications

Temperature abuse had no significant effect on color, oxidation, and volatiles of irradiated pork loins. However, temperature abuse improved water holding capacity of meat, which could be caused by the accelerated hydrolysis of muscle proteins at higher temperature. Irradiation increased redness, sulfur contents in volatiles and off-odor of pork loin. Off-odor and redness induced by irradiation sustained during storage. Among sulfur compounds, the content of dimethyl disulfide decreased gradually while the level of thiourea remained relatively constant. Irradiation also increased water loss, which might be related to the structural damage in membrane during irradiation. This study shows that temperature abuse has little effect on the quality of irradiated pork.

Introduction

During large-scale distribution and handling of meat, especially in export of meat to foreign markets, there are numerous opportunities for meat to be temperature abused. Therefore, it is inevitable for meat products to be exposed to fluctuating temperatures during irradiation, transportation and subsequent storage, which may promote the growth of microorganism including pathogens and accelerate quality changes in meat.

Apart from the proliferation of microorganisms in meat, fluctuating temperature accelerates a number of enzymatic and chemical reactions that can influence the shelf life of irradiated meat. Exposure of meat to increased temperature conditions undoubtedly accelerate proteases activity to breakdown muscle protein into small molecular weight peptides, and long term storage of meat is often associated with extensive softening of meat and color change independent of microorganism. Lipid oxidation may also be accelerated under the elevated temperature conditions. The objective of this study was to determine the effect of temperature fluctuation on the quality of irradiated pork loins.

Materials and methods

Twelve pork loins were obtained directly from a local packing plant. Each loin was sliced into 2.5 cm-thick chops for water holding capacity measurement. The rest was sliced to 1.0-cm-thick chops and the chops were used for color, volatiles and TBARS assays. Chops within each replication were randomly separated into three groups, and each group was assigned to receive 0, 1.5, or 2.5 kGy electron-beam

irradiation. Each chop within a group was further cut into three equal pieces to make three sub-groups: one sub-group were refrigerated (4°C) immediately after irradiation (Trt I); another sub-group was kept at room temperature (22°C) for three hours before refrigeration (Trt II); and the last sub-group (Trt III) were exposed at room temperature for 1 hour three consecutive days with intermittent storage at 4°C between exposures. In each step of meat handling, care was taken to avoid microbial contamination.

Loin pieces were vacuum-packaged individually in low oxygen-permeable bags before irradiation. Color, volatiles and lipid oxidation were analyzed after 0, 14, 28 and 42 days of storage, and water holding capacity and sensory characteristics were evaluated after 0, 14, and 28 days of storage.

Results and Discussion

Irradiation significantly increased the loss of water from loins (Table 1). For the control samples with no temperature abuse (Trt I), both irradiation at 1.5 kGy and 2.5 kGy significantly increased centrifugation loss compared to that of non-irradiated samples. The mechanism for irradiation-induced centrifugation loss in pork loins could be: 1) irradiation may damage the integrity of membrane structure of muscle fibers and 2) irradiation may denature the muscle proteins, thus lowering water holding capacity. After 14 days of refrigerated storage, samples from three consecutive days of exposure to room temperature (Trt III) had lower centrifugation loss than other treatments. Since the meat used in this study is at post-rigor stage, the water holding capacity of meat is gradually improving during storage due to hydrolysis of muscle proteins. Therefore, the improved water holding capacity could be due to accelerated hydrolysis of proteins during temperature abuse, since high temperature increases protease activity. During storage, water holding capacity increased for all loins with various irradiation doses and temperature treatments (Table 1). This may also be due to the hydrolysis of muscle proteins during storage, a continuation of the postmortem changes in muscle.

Irradiated samples have higher redness (a^* value) than control samples (Table 2). Temperature abuse had no effect on the redness of pork loin. Overall, the temperature fluctuations had no effect on the color values of irradiated pork loins. Temperature fluctuation, irradiation and storage had little influence on TBARS of pork loins because the loin chops were vacuumed packaged.

Irradiation induced strong off-odor (Table 3). After irradiation, off-odor intensity increased from around 1.5 points to above 5 points on a 9-point scale. This irradiation off-odor was a pungent, cooked, corn like odor. Temperature fluctuation and storage had no significant effect on irradiation off-odor (Table 3).

Irradiation induces sulfur-containing volatiles, which could be the main reason for irradiation-induced off-odor. Dimethyl disulfide was almost undetectable in non-irradiated samples, but the amount of dimethyl disulfide dramatically increased after irradiation. During storage, the content of dimethyl disulfide gradually reduced and became barely detectable after 28 days of storage (Fig 1). This suggested that dimethyl disulfide might not be the only sulfur volatile contributing to irradiation off-odor because strong irradiation off-odor was still apparent by sensory panelists after 28 days of storage (Table 3). However, no significant amounts of other sulfur volatiles were detected in this study.

Irradiation odor seems to be more related to thiourea content in volatiles than other sulfur compounds (Fig 2). After 42 days of storage, significant amounts of thiourea still remained in meat. This result was in agreement with the sensory data where a sulfur-like off-odor was noted (Table 3). Thiourea content in volatiles increased greatly by irradiation, and increased slightly after 14 days refrigerated storage before decreasing at 42 days of storage (Fig 2).

There was no overall difference in thiourea content among different temperature fluctuation. Combining with sensory evaluation data, this result showed that temperature abuse did not influence the irradiation off-odor of pork loins.

Conclusion

Mild temperature fluctuation had minor effect on color, oxidation, and volatiles of irradiated pork loins. However, temperature fluctuation improved water holding capacity of meat. Irradiation increased redness, sulfur contents in volatiles and off-odor of pork loins. During storage, the content of dimethyl disulfide decreased gradually while the level of thiourea remained relatively constant. Irradiation also increased centrifugation loss that was partly reversed during refrigerated storage, which could be due to the hydrolysis of muscle proteins. This result shows that the quality changes induced by temperature abuse are not a major concern. However, temperature abuse is expected to promote recovery and proliferation of bacteria in irradiated meats and extensive microbial growth can affect the quality of meat, when meats with poor hygienic conditions are used.

Table 1. Water holding capacity influenced by irradiation and treatments of pork loins

Characteristics	Trt I	Trt II	Trt III	SEM
-----0 day-----				
0 kGy	8.1b	8.9b	-	0.5
1.5 kGy	11.3a	10.2a	-	1.2
2.5 kGy	10.9a	10.0a	-	0.9
SEM	0.9	0.9	-	
-----14 day-----				
0 kGyl	8.1bx	8.6x	6.4y	0.5
1.5 kGy	9.0ab	10.0	8.6	0.9
2.5 kGy	10.2ax	9.9x	6.8y	0.8
SEM	0.5	0.6	0.4	2.3
-----28 day-----				
0 kGy	5.7b	7.4	6.0	0.6
1.5 kGy	6.4ab	6.9	6.3	0.7
2.5 kGy	8.0ax	6.2y	6.4y	0.4
SEM	0.6	0.6	0.6	

^{x-y}Means within a row with different superscript differ significantly ($P < 0.05$). n = 4.

^{a-c}Means within a column with different superscript differ significantly ($P < 0.05$).

Trt I: refrigerated immediately after irradiation; Trt II: kept at room temperature for three hours before refrigerated storage; Trt III: were exposed at room temperature for 1 hour at three consecutive days with intermittent storage at 4°C between exposures.

Table 2. Color a* of pork loin effected by irradiation and treatments after storage

Irradiation dose	Trt I	Trt II	Trt III	SEM
-----0 day-----				
0 kGy	13.0b	13.2c	-	0.4
1.5 kGy	14.6a	14.3b	-	0.2
2.5 kGy	15.2ay	15.6ax	-	0.1
SEM	0.4	0.2	-	
-----14 day-----				
0 kGy	12.8b	12.6c	12.5c	0.3
1.5 kGy	15.1ax	14.1by	14.5bxy	0.2
2.5 kGy	15.9a	16.8a	15.9a	0.3
SEM	0.3	0.3	0.4	
-----28 day-----				
0 kGy	14.4b	14.6b	13.3b	0.4
1.5 kGy	15.5a	15.5a	16.1a	0.3
2.5 kGy	16.2a	15.9a	16.3a	0.3
SEM	0.3	0.2	0.4	
-----42 day-----				
0 kGy	-	-	-	-
1.5 kGy	14.9b	15.3	14.7b	0.3
2.5 kGy	16.1a	16.0	16.3a	0.3
SEM	0.3	0.4	0.2	

^{a-c}Means within a column with different superscript differ significantly ($P < 0.05$). n = 4.

^{x-y}Means within a row with different superscript differ significantly ($P < 0.05$).

Trt I: refrigerated immediately after irradiation, Trt II: kept at room temperature for three hours before refrigerated storage, Trt III: were exposed at room temperature for 1 hour at three consecutive days with intermittent storage at 4°C between exposures.

Table 3. Irradiation off-odor as influenced by irradiation and treatments of pork loins

Irr. dose	Trt I	Trt II	Trt III	SEM
-----0 day-----				
0 kGy	1.5b	1.4b	-	0.3
1.5 kGy	5.7a	6.2a	-	0.6
2.5 kGy	6.0a	7.0a	-	0.6
SEM	0.4	0.5	-	
-----14 day-----				
0 kGy	1.3b	1.5c	1.7b	0.3
1.5 kGy	6.9a	5.6b	6.8a	0.4
2.5 kGy	7.1a	7.6a	7.3a	0.5
SEM	0.4	0.3	0.5	
-----28 day-----				
0 kGy	1.4c	1.2b	1.7b	0.4
1.5 kGy	6.2b	5.4a	4.7a	0.5
2.5 kGy	7.3a	6.3a	5.7a	0.6
SEM	0.4	0.5	0.6	

^{ab}Means within a row with different superscript differ significantly ($P < 0.05$). n = 12.

Trt I: refrigerated immediately after irradiation, Trt II: kept at room temperature for three hours before refrigerated storage, Trt III: were exposed at room temperature for 1 hour at three consecutive days with intermittent storage at 4°C between exposures.

Twelve trained sensory panelists characterized the smell of irradiated loins stored under different temperature conditions. A 9-point category scale was used to describe the sensory characteristics and was assigned a score ranging from 1 (none) to 9 (extremely strong), respectively.

Figure 1. Effects of temperature fluctuation and storage on dimethyl disulfide contents ($\times 10^4$ counts) in volatiles of pork loins under different irradiation conditions (Trt I: pork loins went into refrigerated (4°C) immediately after irradiation; Trt II: irradiated pork loins were kept at room temperature (22°C) for three hours before refrigeration; Trt III: after irradiation, pork loins were exposed at room temperature for 1 hour three consecutive days with intermittent storage at 4°C between exposures. Pork chops were irradiated at 0, 1.5 and 2.5 kGy. Volatiles were analyzed after storage at 4°C for 0, 14, 28, and 42 days. A purge-and-trap dynamic headspace GC/MS system was used to identify and quantify the volatiles compounds. A mass selective detector (MSD) was used to identify and quantify volatiles compounds in irradiated samples. The identification of volatiles was achieved by comparing mass spectral data with those of the Wiley Library. The peak area ($\times 10^4$ ion counts) was reported as the amount of volatiles released. $n = 4$).

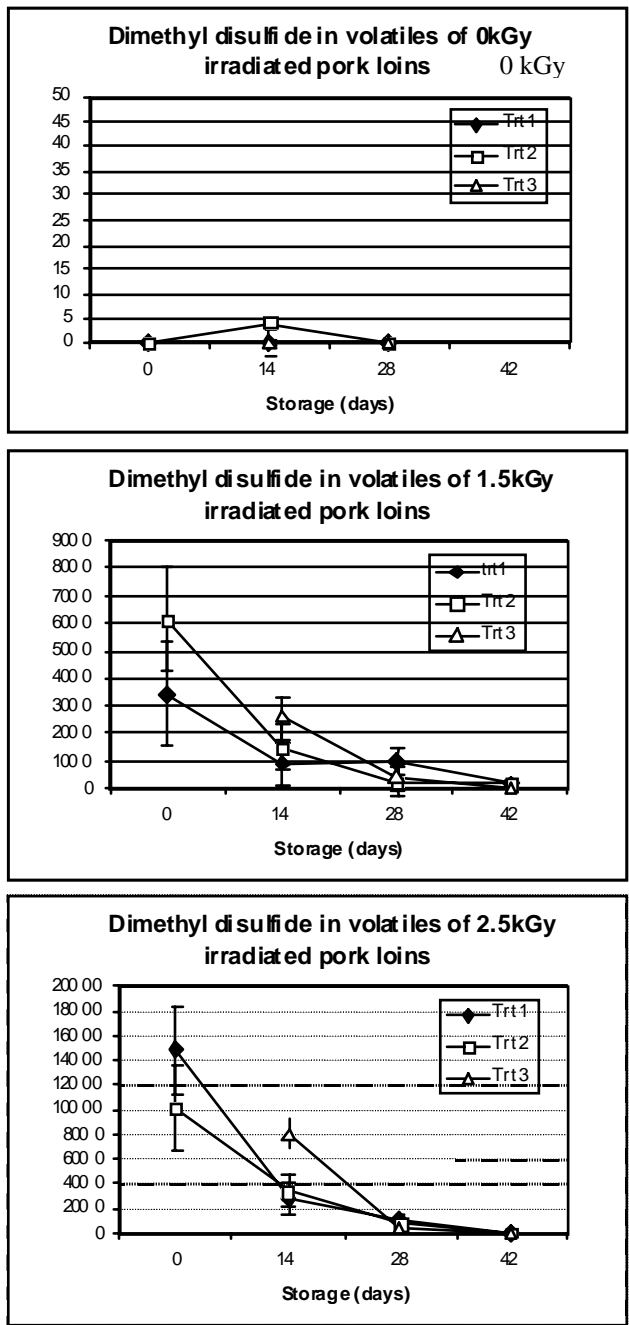


Figure 2. Effects of temperature fluctuation during storage on thiourea content ($\times 10^4$ counts) in irradiated pork loins (Trt I: pork loins went into refrigerated (4°C) immediately after irradiation; Trt II: irradiated pork loins were kept at room temperature (22°C) for three hours before refrigeration; Trt III: after irradiation, pork loins were exposed at room temperature for 1 hour three consecutive days with intermittent storage at 4°C between exposures. Pork chops were irradiated at 0, 1.5 and 2.5 kGy. Volatiles were analyzed after storage at 4°C for 0, 14, 28, and 42 days. A purge-and-trap dynamic headspace GC/MS system was used to identify and quantify the volatiles compounds. A mass selective detector (MSD) was used to identify and quantify volatiles compounds in irradiated samples. The identification of volatiles was achieved by comparing mass spectral data with those of the Wiley Library. The peak area ($\times 10^4$ ion counts) was reported as the amount of volatiles released. $n = 4$)

