Effects of Gamma Irradiation and X-ray Irradiation on Quality, Sensory Characteristics of Beef Patties

Youn Kyung Ham¹, Hyun Wook Kim¹, Lee Choong Hee¹, Cheon Jei Kim¹

¹Department of Food Science and technology of Animal Resources, Konkuk University, Seoul, Republic of Korea

Abstract. The physicochemical properties (pH, color, and texture) and sensory properties of beef patties that irradiated by gamma ray and X-ray were evaluated and compared. Ground beef patties were cooked and vacuum-packaged before irradiation by gamma ray and X-ray at 0, 2.5, 5, 7.5, 10 kGy. The redness of beef patties decreased by irradiation regardless of irradiation method compared to control (p < 0.05). Since gamma irradiation affected the sensory quality more than X-ray irradiation, gamma irradiated samples got lower scores on the sensory evaluation (flavor and overall acceptability) compared to X-ray irradiated samples (p < 0.05). The result of this study suggests that X-ray is more effective irradiation method than gamma irradiation to improve the flavor and overall acceptability of beef patties.

Keywords: food irradiation, beef patty, x-ray, gamma-ray

1. Introduction

Since the 1950s, studies on irradiation of food started, and radiation technology using an gamma ray or electron beam, and X-ray has been known one of the most effective method to improve the food safety [1]. In 1997, FDA approved of utilization of radiation technology to the red meat and meat products, and it has facilitated elimination of pathogenic and spoilage microorganisms in various meat and meat products. Irradiation is non-thermal process so that it can maintain the quality of the products. Also, irradiation can treate the products in packaged state so that reduce the risk of cross-contamination [2]. Among the ionizing irradiation, gamma irradiation is commonly used for irradiation of food including meat. Although gamma irradiation has higher penetrating power than the other sources, there are still safety concerns since it deals with the nuclear substance. Mitchell [3] suggested that consumer prefers the machine irradiation sources to isotope irradiation sources. Besides, Wagner [4] reported that X-ray irradiators can save time and cost compared with gamma irradiators through continuous processing and low energy that readily manageable than gamma ray. Thus, studies on X-ray irradiation on the meat and meat products has been conducted by many researchers recently. The objective of this study was to compare the effect of gamma irradiation and X-ray irradiation on physicochemical properties (pH, color, and texture) and sensory properties of beef patties.

2. Materials and Methods

2.1. Manufacturing and Irradiation of Beef Patties

Frozen beef top round was purchased from a local butcher shop and ground using 8mm plate. Then ground beef was mixed with pork backfat, ice, nitrite pickling salt, sodium tripolyphosphate, sugar, isolated soy protein, pepper, garlic powder, onion powder, ginger powder, spices, and ascorbic acid. After mixing process, about 100g of the mixture was shaped into patties (diameter 10 cm, and thickness 1.5 cm) by using
mould. Beef patties were heated in an oven that preheated at 150°C for about 10 minutes until the core temperature get to 75°C. Cooked patties were cooled to room temperature for 6 hours, then vacuum packaged individually in polyethylene/nylon pouch. Vacuum-packaged beef patties were irradiated at 0(control), 2.5, 5, 7.5, 10 kGy by Gamma ray, X-ray at room temperature. Gamma ray irradiation was conducted using $^{60}$Co irradiator (point source AECL, IR-79, MDS Nordion International Co. Ltd., Canada) in the Advanced Radiation Technology Institute, Korea Atomic Energy Research Institute (Jeoung-Eup, Korea). X-ray irradiation was performed with an LINAC Electron-Accelerator (10 MeV) at the EB-tech (EB-tech Co., Daejeon, Korea).

2.2. pH and Color Evaluation

The 5 g of samples with 20 mL distilled water was homogenized for 60 s using a homogenizer (Ultra-Turrax T25, Janke and Kunkel, Staufen, Germany). The pH of samples was determined with a pH meter (Model 340, Mettler-Toledo GmbH, Schwerzenbach, Switzerland). The color of surface of irradiated beef patties was measured with colorimeter (Chroma meter, CR210, Minolta, Japan) to determine the CIE-L$^*$ value (lightness), a$^*$ value (redness), and b$^*$ value (yellowness). The standard plate that has L$^*$ value; +97.83, a$^*$ value; -0.43, and b$^*$ value; +1.98 was used.

2.3. Texture Profile Analysis (TPA)

The TPA was performed on each sample at room temperature using a spherical probe (5 diameter), attached to a texture analyzer (TA-XT2i, Stable Micro Systems Ltd., Surrey, England). The test conditions were as follows: pre-test speed 2.0 mm/s, post-test speed 5.0 mm/s, maximum load 2 kg, head speed 2.0 mm/s, distance 8.0 mm, and force 5 g. The data of hardness (kg), springiness, cohesiveness, gumminess (kg), and chewiness (kg) were determined as described by Bourne [5].

2.4. Sensory Evaluation

The beef patty samples were evaluated color of appearance, flavor, texture, juiciness, and overall acceptance (1 = extremely undesirable, 10 = extremely desirable). The irradiated samples were cut in cube (1x1x1 cm) and served in random order to the panelists that consisted of 12 members from the Konkuk university. The sensory evaluation was performed under fluorescence light and panelists were instructed to clean their palates between samples using water.

2.5. Statistical Analysis

An analysis of variance was performed on all the variables measured using the general linear model (GLM) procedure of the SAS statistical package [6]. Duncan’s multiple range tests ($p < 0.05$) was used to determine differences between treatment means.

3. Results and Discussion

3.1. pH and Color

The pH values of sample that irradiated by X-ray were slightly higher than that of non-irradiated control sample (Table 1). However, regardless of irradiation method or absorbed dose, irradiation did not influenced significantly on the pH of beef patty samples ($p > 0.05$).

After irradiation treatment, within the treatments have absorbed dose 7.5 kGy, the lightness of gamma ray irradiated patties was lower than X-ray irradiated patties ($p < 0.05$). As absorbed dose of gamma ray increasing, the lightness of gamma irradiated samples showed decreasing tendency though there was no significant difference compared to that of non-irradiated sample. This result is in accordance with the result of study conducted by Park et al. [1]. By the study reported Kim et al. [7], beef color changed into greenish brown by the gamma irradiation. In agreement, the redness of the beef patties decreased by irradiation ($p < 0.05$), except 7.5 kGy irradiated by gamma ray. In this study, gamma irradiation or X-ray irradiation did not influenced on the yellowness of all samples, therefore, significant differences between irradiated and non-irradiated samples did not observed ($p > 0.05$). Among the all treatments, irradiated by X-rat at 7.5 kGy has the lowest yellowness value.

Table 1. Effect of gamma-ray and X-ray irradiation on pH value and color of beef patties
### 3.2. Texture Profile Analysis

The hardness (kg) of X-ray irradiated samples was increased as absorbed dose increased (Table 2). However, the springiness of samples did not affected significantly by the irradiation treatment up to 10 kGy \((p > 0.05)\). The cohesiveness of 5 kGy X-ray irradiated sample showed lower value than gamma irradiated samples \((p < 0.05)\), although, in compare with non-irradiated sample, cohesiveness did not show significant changes by the irradiation. Also, the gumminess (kg) and chewiness (kg) of irradiated patties were not different compared to the control \((p > 0.05)\). Therefore, the effect gamma irradiation and X-ray irradiation on the texture characteristics of beef patties did not observed in the result from this study.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Ionizing sources</th>
<th>Irradiation dose (kGy)</th>
<th>SEM(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>2.5</td>
</tr>
<tr>
<td>Hardness (kg)</td>
<td>Gamma-ray</td>
<td>1.124</td>
<td>1.063</td>
</tr>
<tr>
<td></td>
<td>X-ray</td>
<td>1.124</td>
<td>1.082</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>-</td>
<td>0.055</td>
</tr>
<tr>
<td>Springiness (ratio)</td>
<td>Gamma-ray</td>
<td>0.814</td>
<td>0.812</td>
</tr>
<tr>
<td></td>
<td>X-ray</td>
<td>0.814</td>
<td>0.824</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>-</td>
<td>0.001</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>Gamma-ray</td>
<td>0.452</td>
<td>0.451</td>
</tr>
<tr>
<td></td>
<td>X-ray</td>
<td>0.452</td>
<td>0.448</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>-</td>
<td>0.004</td>
</tr>
<tr>
<td>Gumminess (kg)</td>
<td>Gamma-ray</td>
<td>0.509</td>
<td>0.484</td>
</tr>
<tr>
<td></td>
<td>X-ray</td>
<td>0.509</td>
<td>0.481</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>-</td>
<td>0.025</td>
</tr>
<tr>
<td>Chewiness (kg)</td>
<td>Gamma-ray</td>
<td>0.409</td>
<td>0.393</td>
</tr>
<tr>
<td></td>
<td>X-ray</td>
<td>0.409</td>
<td>0.402</td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td>-</td>
<td>0.023</td>
</tr>
</tbody>
</table>

\(^{1}\)SEM: standard error of the means. \((n=4)\).

\(^{2}\)SEM: standard error of the means. \((n=20)\).

\(^{a}\) Mean values within a column follow by the different letter are significantly different \((p < 0.05)\).

\(^{b}\) Mean values within a row follow by the different letter are significantly different \((p < 0.05)\).
### 3.3. Sensory properties

Table 3. Effect of gamma-ray and X-ray irradiation on sensory properties of beef patties

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Ionizing sources</th>
<th>Irradiation dose (kGy)</th>
<th>SEM&lt;sup&gt;1)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>2.5</td>
</tr>
<tr>
<td>Color</td>
<td>Gamma-ray</td>
<td>8.22</td>
<td>7.83</td>
</tr>
<tr>
<td></td>
<td>X-ray</td>
<td>8.22</td>
<td>8.11</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td>-</td>
<td>0.089</td>
</tr>
<tr>
<td>Flavor</td>
<td>Gamma-ray</td>
<td>7.89</td>
<td>6.94</td>
</tr>
<tr>
<td></td>
<td>X-ray</td>
<td>7.89&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.67&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td>-</td>
<td>0.156</td>
</tr>
<tr>
<td>Texture</td>
<td>Gamma-ray</td>
<td>7.33</td>
<td>7.00</td>
</tr>
<tr>
<td></td>
<td>X-ray</td>
<td>7.33</td>
<td>7.39</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td>-</td>
<td>0.141</td>
</tr>
<tr>
<td>Juiciness</td>
<td>Gamma-ray</td>
<td>7.33</td>
<td>7.11</td>
</tr>
<tr>
<td></td>
<td>X-ray</td>
<td>7.33</td>
<td>7.11</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td>-</td>
<td>0.134</td>
</tr>
<tr>
<td>Overall</td>
<td>Gamma-ray</td>
<td>8.06</td>
<td>7.06&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>acceptability</td>
<td>X-ray</td>
<td>8.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.06&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>SEM</td>
<td></td>
<td>-</td>
<td>0.144</td>
</tr>
</tbody>
</table>

<sup>1</sup>SEM: standard error of the means. (n=12).

<sup>a-b</sup> Mean values within a row follow by the different letter are significantly different (p < 0.05).

Although instrumental redness values of samples affected by irradiation, sensory characteristic (color) of the beef patties did not show significant differences in the scores (p > 0.05) compared to control (Table 3). As absorbed dose increasing, flavor of the beef patties decreased in both irradiation methods. However, it seems that X-ray irradiation induced less decrease of flavor than gamma irradiation in beef patties. The texture and juiciness of irradiated beef patties did not show any distinctive changes by neither irradiation method nor absorbed dose (p > 0.05). Gamma irradiation decreased overall acceptability scores of beef patties largely compared to X-ray irradiation (p < 0.05). Overall acceptability of samples decreased according to an increase of absorbed dose in both irradiation methods.

In conclusion, both gamma irradiation and X-ray irradiation induced changes of the color and sensory characteristics of beef patties. However, X-ray irradiation can be more effective than gamma irradiation for reducing decreases of flavor and overall acceptability of beef patties up to 10 kGy.

### 4. Acknowledgements

This study was supported by Nuclear Research and Development Project of the Ministry of Education (2013-A423-0047), Republic of Korea.

### 5. References


