Lipid oxidation and volatile production in irradiated raw pork batters prepared with commercial soybean oil containing vitamin E

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Abstract

An emulsion-type raw pork batter was prepared using 10\% (meat weight) of backfat or commercial soybean oil enriched with vitamin E to determine the effect of irradiation on lipid oxidation and volatile production during storage. Batters (approximately 100 g) were vacuum- or aerobically packaged and irradiated at 0, 2.5 or 4.5 kGy. Irradiation increased lipid oxidation of aerobically packaged raw pork batters prepared with both backfat and soybean oil. Lipid oxidation of vacuum-packaged pork batters was not influenced by irradiation except for the batter prepared with backfat at day 0. Aerobically packaged batters prepared with soybean oil had lower ($P < 0.05$) TBARS than that with backfat, but vacuum-packaged ones were not different. The sum of volatile compounds with short retention time ($<1.80$) increased by irradiation, and with storage time except for aerobic packaging at day 7. The amount of total volatile compounds had an increasing trend until day 3, but not at day 7. Irradiation increased the production of total volatile compounds in the batters prepared with soybean oil and vacuum packaged, but irradiation effect on volatile production was not consistent with other treatments. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Lipid oxidation; Volatile compounds; Raw pork batter; Vitamin E; Soybean oil

1. Introduction

The Centers for Disease Control (CDC) estimated that approximately 6.5 million cases of food-borne diseases of microbiological and parasitic origin occur in the US each year. Furthermore, the economic impact caused by food supplier losses, law suits, and consumers’ medical and hospital costs is also tremendous (Todd, 1989). The major food sources causing the outbreaks of food-borne diseases are meats, eggs, dairy products, fruits, vegetable, and seafoods. Recent outbreaks of food-borne illness increased consumer awareness of possible contamination with pathogens. Of surveyed consumers, 43\% were very concerned about food safety (AMIF, 1993). Radiation destroys microorganisms by partial or total inactivation of genetic materials in living cells either by its direct effects on DNA, or through the production of radicals and ions that attack DNA indirectly (WHO, 1994). Because of relatively small influence on food itself compared to the living cells, irradiation technology is known to the best method to control pathogens in food including meat products. However, several quality aspects such as lipid oxidation, cholesterol oxidation, and off-flavor production should be considered in irradiating meat products (Ahn et al., 1997, 2000).

The degree of unsaturation is one of the main factors influencing the rate of lipid oxidation. Although
linolenic acid is a minor component in soybean oil, it has a deleterious effect on the oxidative stability and flavor of soybean oils (Liu and White, 1992). Irradiation at 10 and 15 kGy resulted in loss of phopholipids in rice bran and increased the amount of free fatty acids (Shin and Godbler, 1996). The oxidation of lipids in raw meat is closely related to the antioxidant potential of muscle tissues. Vitamin E is a major antioxidant in cell membranes and protects the membrane lipids and cholesterol from peroxidative damages caused by reactive free radicals (Buckley et al., 1995; Liu et al., 1995). Dietary dl-α-tocopherol acetate more than 200 IU/kg decreased lipid oxidation and reduced total volatiles of raw turkey patties after 7 days of storage (Ahn et al., 1997). Lee et al. (1999) found that ascorbyl palmitate significantly reduced oxidation of irradiated oils and its effect was concentration-dependent.

At present, many meat processors started to test market irradiated raw ground meat products. Furthermore, meat industry is petitioning for the approval of irradiation on processed meat. However, the relationship between fatty acid composition, use of antioxidant, and the production of volatiles in irradiated processed meat is not clearly known. The objective of present study was to determine the effect of vitamin E enriched soybean oil on lipid oxidation and volatile production in irradiated raw pork batters with different packaging conditions.

2. Materials and methods

2.1. Sample preparation

Lean pork and pork backfat were purchased from a local packing plant and ground twice through a 9-mm plate. An emulsion-type pork product was prepared using ground meat, NaCl (2% of meat weight), ice water (10% of meat weight), and pork backfat (10% of meat weight). Soybean oil (Preferred Products, Inc., Eden Prairie, MN 55334) was purchased from a local market and added instead of pork backfat as a treatment. Batters (approximately 100 g each) were vacuum packaged in oxygen-impermeable nylon/polyethylene bags (9.3 ml O2/m²/24 h at 0°C, Koch, Kansas City, MO) and stored overnight at 4°C to minimize changes before irradiation. The next morning, half of the vacuum-packaged bags were cut open to make aerobic conditions, and meat batters were irradiated at 0, 2.5, or 4.5 kGy (average absorbed dose; dose rate was 107 kGy/min) using a linear accelerator (Circe IIIR, Thomson CSF Linac, France). The other half was irradiated in vacuum state. To confirm the target dose, two alanine dosimeters per cart were attached to the top and bottom surfaces of the sample. The samples were analyzed 3 h after irradiation.

2.2. Lipid oxidation, fat content, and fatty acid composition

Lipid oxidation was determined as a 2-thiobarbituric acid reactive substances (TBARS) value by using a spectrophotometer (DU series 600, Beckman Instruments, Inc., Fullerton, CA) as described by Ahn et al. (1997). TBARS values were expressed by mg malonaldehyde (MDA) per kg meat. Total fat content was determined by Folch’s extraction method (Folch et al., 1957). Fatty acid methylation was performed with BF3-methanol (14% solution, Supelco, Bellefonte, PA). The fatty acid methyl esters were separated on a Hewlett-Packard Gas Chromatograph (GC, Model 6890, Hewlett-Packard Co., Wilmington, DE) equipped with a flame ionization detector. A split inlet (split ratio, 29:1) was used to inject samples into a HP-5 capillary column (0.25 mm × 30 m × 0.25 μm), and ramped oven temperature was used (80°C for 0.3 min, increased to 180°C, 30°C/min, and increased to 230°C, 6°C/min). Inlet and detector temperature were 180 and 280°C, respectively. Helium was the carrier gas at constant flow of 1.1 ml/min. Detector air, H2, and make-up gas (He) flows were 300, 30, and 28 ml/min, respectively.

2.3. Vitamin E analysis

Raw pork batter (2 g) was homogenized in 10 ml (wt/vol) of phosphate-EDTA buffer (pH 7.0). The amounts of α- and γ-tocopherol were determined using high-performance liquid chromatography (HPLC, Shimadzu Co., Kyoto, Japan) as described by Ahn et al. (1995).

2.4. Volatile compounds analysis

Precept II and Purge-and-Trap concentrator 3000 (Tekmar-Dohrmann, Cincinnati, OH) were used to purge and trap volatile compounds, and a GC (Hewlett-Packard, Model 6890, Wilmington, DE) equipped with a flame ionization detector (FID) was used to analyze volatile compounds from meat batters. Meat batter (3 g) was sampled and analyzed using the conditions described by Ahn et al. (1997).

2.5. Statistical analysis

One-way analyses of variance (ANOVA) was used to determine the effect of added fat sources on major fatty acids, fat content, and vitamin E content by SAS software (SAS, 1989). Two-way ANOVA was performed to determine the effect of irradiation dose and fat source on the TBARS value and the production of...
volatile compounds. Tukey’s multiple range test was used to compare differences among means (Steel and Torrie, 1980). Means and their pooled standard errors (SEM) were reported.

3. Results and discussion

3.1. Fatty acid composition, fat content, vitamin E content

The raw pork batter with commercial soybean oil had significantly higher linoleic acid (C18:2) than that with backfat (Table 1). Reported oleic acid contents in lard and soybean oil were generally 44 and 24%, respectively (ISEO, 1994). The results showed that the batter prepared from backfat had similar amount of oleic acid percentage but the batter prepared from soybean oil had 32.46%, which was higher than oil (Table 1). Linoleic acid contents were 10 and 54% in lard and soybean oil, respectively, which had higher percentage than the present results of the batter. It is possibly due to the saturation during making the batters. Fat content of the raw pork batter with backfat (11.51%) was lower than that with soybean oil (12.80%, \( P<0.05 \)) because of the other substances such as water in the backfat. The \( \alpha \)- and \( \gamma \)-tocopherol content of the commercial soybean oil was 99.8 and 691.1 ppm, respectively. Jo and Ahn (2000) reported that the amount of gamma tocopherol in sausage prepared with flaxseed oil containing vitamin E was 100- to 200-fold higher than that prepared with lard or corn oil. Similarly, the raw pork batter prepared with commercial soybean oil had about 35 times higher \( \alpha \)-tocopherol contents and about 200 times higher \( \gamma \)-tocopherol content than that prepared with backfat when cooked because of added amount of vitamin E into the commercial products (data are not shown).

3.2. Lipid oxidation

Irradiation at 4.5 kGy dose increased the TBARS value of aerobically packaged raw pork batter prepared with both fat sources except for the batter with soybean oil at day 7 (Figs. 1A and B). Katusin-Razem et al. (1992) reported that irradiation-induced oxidative changes were dose-dependent, and the presence of oxygen had a significant effect on the rate of oxidation. Aerobic packaging also increased the lipid oxidation of raw pork batter during the 7-day storage regardless of fat sources used. Statistical analysis indicated that the TBARS of raw pork batter were affected by fat source in aerobic packaging (\( P<0.05 \)). Theoretically, the raw pork batter with soybean oil should have higher lipid oxidation rate because of higher linoleic acid content, but had lower TBARS at days 3 and 7 (\( P<0.05 \)). Galvin et al. (1998) reported that high vitamin E content in muscle via the dietary supplementation reduced lipid and cholesterol oxidation in chicken muscle. Jo and Ahn (2000) also reported that vitamin E contained in the flaxseed oil helped to maintain low TBARS of cooked pork sausages during storage even though the sausage prepared with flaxseed oil had higher amount of linolenic acid. With vacuum packaging, the TBARS of raw pork batter prepared with backfat increased only at day 0 by irradiation (Fig. 1C), but that of the other treatment combinations (irradiation × fat sources) was not changed. The TBARS of vacuum-packaged raw pork batter prepared with soybean oil did not change by irradiation or by storage (Fig. 1D). Therefore, the results indicated that lipid oxidation did not develop without oxygen.

3.3. Volatile compounds analysis

The sum of volatile compounds coming out before 1.80 min of retention time increased by irradiation and also by storage (Fig. 2). Three to eight volatile compounds were detected but they could not be separated by present method used. With aerobic packaging, the raw pork batter prepared with soybean oil produced smaller amounts of volatiles coming out at early stage of volatile analysis than those with the backfat (Figs. 2A and B). The pork batter prepared with soybean oil contained higher amount of polyunsaturated fatty acids than the backfat, high vitamin E

<table>
<thead>
<tr>
<th>Fat used</th>
<th>C14:0</th>
<th>C16:0</th>
<th>C16:1</th>
<th>C18:0</th>
<th>C18:1</th>
<th>C18:2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backfat</td>
<td>0.07</td>
<td>22.96a</td>
<td>0.31</td>
<td>25.16a</td>
<td>47.07a</td>
<td>5.42b</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>0.01</td>
<td>13.76b</td>
<td>0.19</td>
<td>8.36b</td>
<td>32.46b</td>
<td>45.26a</td>
</tr>
<tr>
<td>SEMb</td>
<td>0.033</td>
<td>0.564</td>
<td>0.090</td>
<td>0.366</td>
<td>1.154</td>
<td>0.779</td>
</tr>
</tbody>
</table>

\( a \)Means with different letters within a column are significantly different (\( P<0.05 \)), \( n=6 \).

\( b \)SEM: Pooled standard errors of the mean.
content in the product should have slowed the development of lipid oxidation in that sample. Irradiation increased the amount of volatile compounds eluting at early stage of analysis (retention time < 1.8 min) regardless of fat sources or packaging method. The amount of volatile compounds with very short retention time (< 1.80) was smaller in vacuum packaged than in aerobically packaged samples (P < 0.05), but was not influenced by oil used. Jo et al. (1999) also reported many unknown volatile compounds with short retention time in irradiated cooked sausages. They suggested that those compounds would be non-polar small hydrocarbons and could be important for irradiation odor. Further investigation for the identification of these volatile compounds and relationship of these compounds with irradiation off-flavor is needed.

The amount of total volatile compounds was rather complicated. With aerobic packaging, the total amount of volatile compounds in raw pork batter prepared with backfat increased by irradiation at day 0, but the difference in total volatile content between irradiated and non-irradiated pork batters disappeared after 3 days of storage (Fig. 3A). The amount of total volatile in raw pork batters prepared with soybean oil and irradiated at 0 and 2.5 kGy increased during storage, but that of the 4.5 kGy did not probably because of the large sample-to-sample variations (Fig. 3B). Irradiation had no effect on the amount of total volatile of vacuum-packaged pork batters prepared with soybean oil. Raw pork batter

Fig. 1. TBARS values (mg malondialdehyde/kg meat) of irradiated raw pork batter: (A) prepared with backfat and aerobically packaged, (B) prepared with commercial vitamin E added soybean oil and aerobically packaged, (C) prepared from backfat and vacuum-packaged, (D) prepared with commercial vitamin E added soybean oil and vacuum-packaged. Different letters (a,b) within the same storage day are significantly different (P < 0.05). Different letters (x–z) within the same irradiation dose are significantly different (P < 0.05).
prepared with soybean oil produced lower amount of total volatile than the backfat at day 0 ($P < 0.05$), but no difference was found at days 3 and 7. The amounts of total volatiles in vacuum-packaged raw pork batters increased by storage except for the samples irradiated at 4.5 kGy (Figs. 3C and D). The pork batter prepared with soybean oil produced lower amount of total volatiles than the backfat. The trend in the production of total volatiles did not agree well with the TBARS values (Figs. 1 and 3). The amounts of total volatile compounds were not different, but lipid oxidation was lower in vacuum-packaged raw pork batter than the aerobic-packaged. One of the reasons could be headspace oxygen in sample vial, which could have reacted with the sample and produced more volatile compounds during sample holding and analysis. Ahn et al. (1999) reported that helium flush or helium flush combined with oxygen absorber were useful in eliminating residual oxygen and minimized oxidative changes in meat during sample holding time. Among individual volatile compounds, the production of 2-methylpropanal, 2-methylbutanal, and pentanal had similar trends to the amount of total volatile ($P < 0.05$, data are not shown). Isopropanal, pentanal, sec-butanol, and 1-dodecanone were also detected from the method used, but the results were inconsistent. Hexanal, known as an indicator of lipid oxidation and meat flavor deterioration (Shahidi and Pegg, 1994), was not found from the raw pork batter prepared either backfat or soybean oil. Considering minimal TBARS and no hexanal

Fig. 2. Amount of volatile compounds with short retention time ($< 1.80$) from raw pork batter prepared with pork backfat or commercial soybean oil containing vitamin E: (A) prepared with backfat and aerobically packaged, (B) prepared with commercial vitamin E added soybean oil and aerobically packaged, (C) prepared with backfat and vacuum-packaged, (D) prepared with commercial vitamin E added soybean oil and vacuum-packaged. Different letters (a–c) within the same storage day are significantly different ($P < 0.05$). Different letters (x–z) within the same irradiation dose are significantly different ($P < 0.05$).
production in both raw pork batters prepared with backfat and soybean oil suggested that lipid oxidation was not the major cause of quality deterioration in irradiated pork batters.

Acknowledgements

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References


![Fig. 3. Amount of total volatile compounds from raw pork batter prepared with pork backfat or soybean oil containing vitamin E: (A) prepared with backfat and aerobically packaged, (B) prepared with commercial vitamin E added soybean oil and aerobically packaged, (C) prepared from backfat and vacuum-packaged, (D) prepared with commercial vitamin E added soybean oil and vacuum-packaged. Different letters (a–c) within the same storage day are significantly different ($P<0.05$). Different letters (x–z) within the same irradiation dose are significantly different ($P<0.05$).](image-url)


