Effects of replacing pork back fat with vegetable oils and rice bran fiber on the quality of reduced-fat frankfurters

Yun-Sang Choi a, Ji-Hun Choi a, Doo-Jeong Han a, Hack-Youn Kim a, Mi-Ai Lee a, Jong-Youn Jeong b, Hai-Jung Chung c, Cheon-Jei Kim a, c*

a Department of Food Science and Biotechnology of Animal Resources, Konkuk University, 1 Hwayang-dong, Gwangjin-gu, Seoul 143-701, Republic of Korea
b Department of Animal Science, University of Wisconsin-Madison, Muscle Biology and Meat Science Building, 1805 Linden Drive West, Madison, WI 53706, United States
c Department of Food Science and Nutrition, Daejin University, Sundan-ri, Pochon-si, Kyunggi 487-711, Republic of Korea

1. Introduction

Frankfurters are one of the most popular traditional meat products in the world, and are mostly produced from pork, back fat, salt, sugar, garlic, nitrite, and various spices (Ayo, Carballo, Solas, & Jimenez-Colmenero, 2008). In general, frankfurters may contain animal fat up to 30%. Fat in meat products plays a major role in forming stable emulsions, reducing cooking loss, improving water holding capacity and binding properties, forming rheological and structural properties and providing juiciness and hardness to the products (Hughes, Cofrades, & Troy, 1997; Pietrasik & Duda, 2000). However, diets with high animal fat content (especially saturated fatty acids and cholesterol) have been related to the increased incidence of obesity, hypertension, cardiovascular diseases, and coronary heart diseases (Ozvural & Vural, 2008; Vural & Javidipour, 2002). As a result, the popularity of meat products with high levels of animal fat has decreased (Vural & Javidipour, 2002). Consumers are increasingly prefer to lower fat content while retaining good flavor and overall acceptability (Lin & Huang, 2008). The increasing demand for low-fat diets has led to the food industry to develop or modify traditional food products to contain less animal fat (Bloukas & Paneras, 1993; Choi et al., 2009; Garcia, Dominguez, Galvez, Casas, & Selgas, 2002; Mittal & Barbut, 1994). Consistent with this trend, manufacturers have reduced the fat content of frankfurters, typically by substituting vegetable oils for animal fat.

Vegetable oils are free of cholesterol and have a higher ratio of unsaturated to saturated fatty acids than animal fats (Liu, Huffman, & Egbert, 1991), however, the use of vegetable oils does not seem technologically suitable because of their different physical properties such as color, flavor and free fatty acid composition (Pappa, Bloukas, & Arvanitoyannis, 2000). Therefore, hydrogenation and inter-esterification procedures have been successfully developed to modify the physical and chemical properties of vegetable oil (Liu et al., 1991; Vural, Javidipour, & Ozbas, 2004). Vural and Javidipour (2002) indicated that the replacement of beef fat with partially inter-esterified vegetable oils in frankfurters could improve the nutrient quality due to modification of the fatty acid composition. Liu et al. (1991) noted that vegetable oils in ground beef patties could reduce caloric and cholesterol content without detrimentally affecting the palatability of the product. Thus, the incorporation of vegetable oil in frankfurters to replace animal fat may have a positive effect on consumer health.

Dietary fibers are extracted from cereals, fruits and vegetables, and different types of dietary fibers have different structures and chemical compositions. Accordingly, the different types of dietary fiber are of nutritional and technological interest (Thebaudin, Lefebvre, Harrington, & Bourgeois, 1997). In particular, among the cereal sources of dietary fiber, rice bran contains many valuable substances such as fiber, proteins, and minerals required for...
human health (Watchararuji, Goto, Sasaki, & Shotipruk, 2008). The major component of dietary fiber in rice bran can lower the risk of cancer and coronary heart diseases (Choi, Jeong, et al., 2008), and can be used to reduce blood cholesterol levels and prevent obesity (Sera et al., 2005). Recently, rice bran has been introduced as a dietary fiber source (Choi, Choi, et al., 2008). However, the application of rice bran is limited by very rapid lipid oxidation, because rice bran has considerable quantities of lipid resulting in the development of off-flavor due to the presence of enzymes such as lipase (Choi, Jeong, et al., 2008). For this reason, fat and starch should be removed from rice bran fiber for commercial use. Research on meat products using both vegetable oil and rice bran fiber is limited.

The objective of this study was to investigate the effect of replacing animal fat with various vegetable oils emulsified with rice bran fiber on the proximate compositions, energy values, pH, cooking yields, TBA values, cholesterol content, free fatty acid, and sensory properties of reduced-fat frankfurters.

2. Materials and methods

2.1. Preparation and processing of rice bran fiber extract

The dietary fiber was extracted using the modified AOAC enzymatic–gravimetric method (AOAC, 1995). The rice bran (moisture content: 12.12 g/100 g, protein content: 12.32 g/100 g, fat content: 20.31 g/100 g, ash content: 8.73 g/100 g, dietary fiber content: 28.60 g/100 g, pH 6.85, lightness (L*-value): 68.85, redness (a*-value): 3.49, yellowness (b*-value): 18.07) from a Japonica rice cultivar (Oryza sativa L.) was purchased from in Geochang, Gyeongsangnam-do, Korea, ground in a mill, passed through a 25 mesh sieve roasted at 105 °C, allowed to equilibrate at room temperature (20 °C), then washed with 99.9% ethanol (preheated to 60 °C), followed by filtration. The residue was washed three times with four volumes of hot water (100 °C) over-night using an air oven and then cooled. The rice bran fiber (moisture content: 11.73 g/100 g, protein content: 21.91 g/100 g, fat content: 4.31 g/100 g, ash content: 7.42 g/100 g, dietary fiber content: 53.25 g/100 g, pH 7.07, lightness (L*-value): 66.10, redness (a*-value): 4.73, yellowness (b*-value): 16.06) was placed in polyethylene bags and vacuum-sealed (FJ-500XL, Fujee Tech., Seoul, Korea). It was then stored at 4 °C until used for product manufacture (Choi et al., 2009).

2.2. Frankfurter preparation and processing

Fresh pork (M. biceps femoris, M. semitendinosus, M. semimembranosus, from castrated boars; Landrace × Yorkshire × Duroc; 5 months old, moisture 71.97%, fat 4.96%, protein 15.82%) and pork back fat (moisture 12.61%, fat 85.64%) were purchased from a local processor at 48 h postmortem. All subcutaneous and intramuscular fat and visible connective tissue were removed from fresh ham muscle. Lean materials were ground through an 8 mm plate. The pork back fat was also ground through an 8 mm plate. The ground tissues was vacuum packaged (FJ-500XL, Fujee Tech., Seoul, Korea) and stored at 0 °C until required for product manufacture. Suitable amounts of the muscle and fat were tempered at 4 °C for 24 h prior to meat batter preparation. Five commercial vegetable oils were used to replace pork fat; olive oil, corn oil, soybean oil, canola oil and grape seed oil; obtained from a local market. All vegetable oils were pre-emulsified on the day of use. Eight parts hot water (75 °C) were mixed for 2 min with one part sodium caseinate. The mixture was emulsified with 10 parts oil for 3 min (Paneras & Bloukas, 1994). Six different frankfurters were produced (Choi et al., 2009). The first frankfurter was the control prepared with 30% pork back fat. The other five frankfurters were prepared with pre-emulsified olive, corn, soybean, canola or grape seed oil. The oils were used at 10% in combination with 10% back fat and 2% rice bran fiber. Pork meat was homogenized and emulsified for 1 min in a silent cutter (Cutter Nr-963009, Hermann Scharfen GmbH & Co., Postfach, Germany). About 1.5% NaCl, 0.2% sodium tripolyphosphate, 0.01% sodium nitrite, 0.5% sugar, 0.08% monosodium glutamate, 0.05% onion powder, 0.05% garlic powder, were added to meat after being dissolved in water and chilled (2 °C), and then mixed for 1 min. Rice bran fiber was added to the samples at 2% and pork back fat or pre-emulsified vegetable oil was added after 3 min and the batters were emulsified for 6 min. A temperature probe (Kane-May, KM330, Harlow, UK) was used to monitor the temperature of the emulsion, which was maintained below 10 °C throughout preparation. After emulsification, meat batter was stuffed into collagen casings (#240, NIPPI Inc., Tokyo, Japan; approximate diameter of 25 mm) using a stuffer (Stuffer IS-8, Sirmian, Marsango, Italy). The meat samples were then heated at 75 ± 2 °C for 30 min in a water bath (Model 10-101, Dae Han Co., Seoul, Korea). The cooked meat batters were cooled with cold water (15 °C). The frankfurters were then placed in polyethylene bags, vacuum packaged and maintained below 10 °C during frankfurter preparation. This was performed in triplicate for each frankfurter (using frankfurters of 10 kg). All analyses were carried out in triplicate for each formulation.

2.3. Proximate composition

Compositional properties of the frankfurters were determined using AOAC (1995). Moisture content was determined by weight loss after 12 h of drying at 105 °C in an oven (SW-90D, Sang Woo Scientific Co., Bucheon, South Korea). Fat content was determined by a Soxhlet solvent extraction system (Soxtec® Avanti 2050 Auto System, Foss Tectator AB, Höganas, Sweden) and protein was determined by an automatic Kjeldahl nitrogen analyzer (Kjeltec® 2300 Analyzer Unit, Foss Tectator AB, Höganas, Sweden). Ash was determined according to AOAC (1995) method 923.03. Carbohydrate contents were calculated by the difference.

2.4. Calorific content

Total calorie estimates (kcal) for frankfurters were calculated on the basis of a 100 g portion using Atwater values for fat (9 kcal/g), protein (4.02 kcal/g), and carbohydrate (3.87 kcal/g) (Mansour & Khalil, 1999).

2.5. pH

The pH of the frankfurters were measured in a homogenate (Ultra-Turrax T25, Janke & Kunkel, Staufen, Germany) prepared with 5 g of sample and distilled water (20 ml) using a pH meter (Model 340, Mettler-Toledo GmbH, Schwerzenbach, Switzerland). All determinations were performed in triplicate.

2.6. Cooking yield

Frankfurters were weighed before heat processing and after chilling at 2 °C for 24 h. The cooking yield was determined from their weights and expressed as a percentage of the initial weight.
2.7. TBA values

Lipid oxidation was assessed in triplicate by the 2-thiobarbituric acid (TBA) method of Tarladgis, Watts, Younathan, and Dungan (1960) with minor modifications. A 10 g sample was blended with 50 ml distilled water for 2 min and then transferred to a distillation tube. The cup used for blending was washed with an additional 47.5 ml of distilled water, which was added to the same distillation flask with 2.5 ml 4 M HCl and a few drops of an antifoam agent, silicone oil (KMK-73, Shin-Etsu Silicone Co. Ltd., Seoul, Korea). The mixture was distilled and 50 ml distillate was collected. Five milliliters of 0.02 M 2-thiobarbituric acid in 90% acetic acid (TBA-reagent) was added to a vial containing 5 ml of the distillate and mixed well. The vials were capped and heated in a boiling water bath for 30 min to develop the chromogen and cooled to room temperature. The absorbance was measured at 538 nm, against a blank prepared with 5 ml distilled water and 5 ml TBA-reagent, using a UV/vis spectrophotometer (Optizen 2120 UV plus, Mecasys Co. Ltd., Daejeon, Korea). Thiobarbituric acid-reactive substances (TBARS) were calculated from a standard curve (8–50 nmol) of malondialdehyde (MA), freshly prepared by acidification of TEP (1,1,3,3-tetraethoxy propane). Reagents were obtained from Sigma (UK). The TBA levels were calculated as mg MA/kg sample.

2.8. Cholesterol analysis

The cholesterol content was determined as described by Flaczky, Rudzinska, Wasowicz, Korczak, and Amarowicz (2006). Lipids were extracted by the Folch, Lee, and Sloane Stanley (1957) mixture, and the sample was saponified with 1 M KOH in methanol and the unsaponifiable fraction was extracted with diethyl ether. The remaining samples were silylated by bis (trimethylsilyl) trifluoracetamide (BSTFA) with 1% trimethylchlorosilane (TMCS) and then were analyzed by gas chromatography (GC). A Hewlett–Packard 5890 gas chromatograph split (1:25) mode, with a FID detector and capillary column DB-5 (30 m × 0.32 mm × 0.25 μm; J&W Scientific Inc., Folsom, CA, USA) equipped with an internal standard.

2.9. Fatty acid composition

One hundred milligrams of lipid were esterified with a solution of ammonium chloride and sulphuric acid in methanol (Baggio & Bragagno, 2006). Fatty acid methyl esters were separated by a gas chromatograph (Palo Alto, Varian Inc., CA, USA) equipped with a split injector (75:1), fused silica capillary column (50 m × 0.25 mm i.d., 0.25 μm film thickness of polyethylene glycol) (CP-SIL 88, Varian Inc., Cromapak, Netherlands), flame ionization detector and workstation (Borwin, France). The initial temperature of the column was 180 °C for 2 min and it was programmed to rise to 225 °C at 5 °C/min, the injector temperature was set at 270 °C and the detector temperature at 300 °C. The carrier-gas was hydrogen at a flow rate of 0.5 ml/min and nitrogen was used as the make-up gas at 30 ml/min. The fatty acids were identified by comparison of the retention times of sample with those of the standards and by spiking. A total of 37 saturated, monounsaturated and polyunsaturated fatty acid standards (Supelco 37 Component FAME Mix #47885-U, Supelco®, Philadelphia, USA) were used to verify the identity and the accuracy of the method. Quantification was as area percentages.

2.10. Sensory evaluation

A trained 30-member panel consisting of researchers of the Department of Food Sciences and Biotechnology of Animal Resources at Konkuk University in Korea was used. Each frankfurter was evaluated in terms of color, flavor, juiciness, tenderness, and overall acceptability. Frankfurters were cooked to a center temperature of 75 °C for 30 min in a water bath (Model 10-101, Dae Han Co., Seoul, Korea), cooled to 21 °C, cut into quarters (size: 5 × 5 × 3 cm), and served to the panelists randomly. Each sample was coded with a randomly selected three-digit number. Sensory evaluations were performed under fluorescent lighting. Panelists were instructed to cleanse their palates between samples using water. The color (1 = extremely undesirable, 10 = extremely desirable), flavor (1 = extremely undesirable, 10 = extremely desirable), tenderness (1 = extremely tough, 10 = extremely tender), juiciness (1 = extremely dry, 10 = extremely juicy), and overall acceptability (1 = extremely undesirable, 10 = extremely desirable) of the cooked samples were evaluated using a 10-point descriptive scale. This analysis was conducted using the Hedonic test described by Choi, Jeong, et al. (2008).

2.11. 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 (1999). Duncan’s multiple range test (P < 0.05) was used to determine the differences between treatment means.

3. Results and discussion

3.1. Proximate composition and energy value

The proximate composition and energy value of frankfurters formulated with various vegetable oils (olive, corn, soybean, canola, and grape seed oil) and with 2% dietary fiber extracted from rice bran are shown in Table 1. The moisture content was higher (P < 0.05) in the treatments with vegetable oil and rice bran fiber than the control because these samples were formulated with

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Control</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (g/100 g)</td>
<td>47.69 ± 0.71</td>
<td>57.26 ± 0.33</td>
<td>56.94 ± 0.50</td>
<td>56.36 ± 0.82</td>
<td>56.20 ± 0.69</td>
<td>56.21 ± 1.09</td>
</tr>
<tr>
<td>Protein (g/100 g)</td>
<td>13.69 ± 0.69</td>
<td>13.01 ± 0.48</td>
<td>13.23 ± 0.57</td>
<td>13.01 ± 0.70</td>
<td>13.13 ± 0.65</td>
<td>13.09 ± 0.91</td>
</tr>
<tr>
<td>Fat (g/100 g)</td>
<td>32.58 ± 0.77</td>
<td>24.58 ± 0.71</td>
<td>25.09 ± 0.51</td>
<td>25.07 ± 0.51</td>
<td>25.09 ± 0.52</td>
<td>25.47 ± 0.70</td>
</tr>
<tr>
<td>Ash (g/100 g)</td>
<td>1.81 ± 0.06</td>
<td>1.94 ± 0.04</td>
<td>1.93 ± 0.01</td>
<td>1.93 ± 0.01</td>
<td>1.91 ± 0.03</td>
<td>1.93 ± 0.02</td>
</tr>
<tr>
<td>Carbohydrate (g/100 g)</td>
<td>4.23 ± 0.97</td>
<td>3.22 ± 0.67</td>
<td>2.82 ± 0.64</td>
<td>3.63 ± 0.75</td>
<td>3.67 ± 0.98</td>
<td>3.29 ± 1.77</td>
</tr>
<tr>
<td>Energy value (kcal/100 g)</td>
<td>365.27 ± 5.84</td>
<td>286.45 ± 4.44</td>
<td>290.36 ± 4.46</td>
<td>292.47 ± 4.53</td>
<td>293.29 ± 4.03</td>
<td>295.12 ± 5.46</td>
</tr>
</tbody>
</table>

All values are mean ± standard deviation of three replicates (n = 30).

* A control: pork back fat; T1: olive oil, T2: grape seed oil, T3: corn oil, T4: canola oil, T5: soybean oil.

** P means within a row with different superscript letters are significantly different (P < 0.05).
added rice bran fiber which had higher water retention and improved emulsion stability (Choi et al., 2009). The highest moisture content was found in the treatment with olive oil and rice bran fiber (T1). Vural et al. (2004) reported similar results for frankfurters made with the inter-esterified vegetable oils and sugarbeet fiber. Choi et al. (2007) and Choi, Jeong, et al. (2008) reported that rice bran fiber provides higher water retention, that is, the addition of rice bran fiber increased the moisture content of frankfurter. The protein content was not significantly different between the controls and the treatments. The fat content was lower ($P < 0.05$) in the treatments formulated with vegetable oil and rice bran fiber (replacing pork fat) than the controls containing animal fat. The overall fat content of the frankfurters were close to the targeted levels. The olive oil treatment (T1) had the lowest fat content among the treatments. This has been reported previously for various meat products (Luruena-Martinez, Vivar-Quintana, & Revilla, 2004; Ozvural & Vural, 2008; Vural et al., 2004; Yildiz-Turp & Serdaroğlu, 2008). The ash content was higher ($P < 0.05$) in the treatments with vegetable oil and rice bran fiber than the control, due to ash production from the rice bran itself (Choi et al., 2007; Choi, Jeong, et al., 2008). Frankfurters had a carbohydrate content ranging from 2.82% to 4.23%, where the highest carbohydrate content was found in the control without vegetable oil and rice bran fiber. The carbohydrate content was not significantly ($P > 0.05$) different among the various treatments containing vegetable oil and rice bran fiber of frankfurters. These results are similar to those obtained by Choi, Choi, et al. (2008) for low-fat rice bran fiber added to tteokgalbi (a Korean traditional meat product).

The differences in energy value of frankfurters formulated with vegetable oils and rice bran fiber were significant (Table 1). The higher ($P < 0.05$) energy value was in the control (367.27 kcal/100 g) with 30% animal fat compared to the other treatments. The energy values of the frankfurters containing vegetable oil and rice bran fiber ranged from 286 to 295 kcal/100 g, and the olive oil treatment had the lowest ($P < 0.05$) value. Reduced-fat frankfurters have approximately 20–22% less energy than the control frankfurters containing animal fat. Grigelmo-Miguel, Abadias-Serós, and Martin-Belloso (1999) reported similar results for low-fat, high-fiber containing frankfurters. Cengiz and Gokoglu (2005) indicated that frankfurter-type sausages with reduced-fat and containing fat replacer were lower in energy and cholesterol contents. Also, Choi, Choi, et al. (2008) noted that low-fat Korean traditional meat products with rice bran fiber provide lower energy values.

### 3.2. pH, cooking yield and TBA value

The effect of the addition of rice bran fiber and the replacement of pork back fat by various vegetable oils on the pH of the frankfurters is shown in Table 2. The pH was higher in frankfurters formulated with vegetable oil and rice bran fiber than in the control (6.25). In the treatment samples, pH ranged from 6.46 to 6.47 and was not significantly ($P > 0.05$) different among treatments. Similar results were obtained by Vural et al. (2004) who studied the effects of replacing animal fat with inter-esterified vegetable oils and sugarbeet fiber on the quality of frankfurters. Choi, Jeong, et al. (2008) reported that the addition of rice bran fiber increased the pH value of frankfurters. The pH value increased when the frankfurker contained vegetable oil and rice bran fiber because rice bran fiber contains minerals such as iron, phosphorus, and calcium (Chotimarkorn, Benjakul, & Silalai, 2008; Watchararuji et al., 2008).

The cooking yield of frankfurters depends on the cooking temperature (Kim & Chin, 2007), cooking time (Banon, Nieto, Castillo, & Alvarez, 2008), the ingredients (Huang, Shiu, Liu, Chu, & Hwang, 2005), and the amount of the fat in the products (Hughes et al., 1997). Table 2 shows the cooking yield of reduced-fat frankfurters formulated with various vegetable oils and with 2% rice bran fiber. The cooking yield was higher ($P < 0.05$) in those formulated with vegetable oil and rice bran fiber than in the control. However, there were no significant ($P > 0.05$) differences among the treatments. This observation was previously reported for various frankfurters (Cengiz & Gokoglu, 2005; Hughes et al., 1997; Luruena-Martinez et al., 2004; Mittal & Barbut, 1994; Yang, Choi, Jeon, Park, & Joo, 2007), patties (Liu et al., 1991; Park et al., 2005), and meatball (Hsu & Yu, 2002). Park et al. (2005) noted that reducing the animal fat content in meat products by replacement with vegetable oil reduced cooking loss. Luruena-Martinez et al. (2004) demonstrated that processing yield was affected by locust bean/xanthan gum replacement. Choi, Jeong, et al. (2008) reported that frankfurters containing rice bran fiber had significantly lower cooking loss than samples with no added fiber. Meat products appear to have improved water holding capacity and emulsion stability due to added dietary fiber, which leads to a higher cooking yield.

The effect of the various vegetable oils on lipid oxidation of frankfurters on day one is shown in Table 2. The analysis of variance indicates that the TBA values were significantly affected by the vegetable oil treatments. The TBA values for all vegetable oil samples were significantly higher than those for the control containing no added vegetable oil due to the fact that added vegetable oils gave differences in fatty acid composition. The highest TBA value was found in those with soybean oil and rice bran fiber (T5). However, all samples had TBA values within acceptable limits (<1.0) (Yildiz-Turp & Serdaroğlu, 2008). These results were in agreement with Paneras and Bloukas (1994) who found that among those in which pork back fat was substituted with various vegetable oils, low-fat frankfurters with olive oil had the lowest TBA values, while those with soybean oil had the highest due to their free fatty acid composition. Bloukas, Paneras, and Fournitzis (1997) described the effects of replacing pork back fat with olive oil on the processing and quality characteristics of sausage. Olive oil increased TBA values compared with the control, and those containing higher amounts of olive oil had higher TBA values. Kayardid and Gok (2003) and Yildiz-Turp and Serdaroğlu (2008) demonstrated that replacing beef fat with olive oil and hazelnut oil improved the quality characteristics of fermented sausage.

**Table 2**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Control</th>
<th>Treatments&lt;sup&gt;A&lt;/sup&gt;</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.25 ± 0.03&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.46 ± 0.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.47 ± 0.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.47 ± 0.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.46 ± 0.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.46 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Cooking yields (g/100 g)</td>
<td>91.95 ± 0.77&lt;sup&gt;b&lt;/sup&gt;</td>
<td>93.41 ± 0.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>93.13 ± 0.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>93.22 ± 0.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>93.11 ± 0.37&lt;sup&gt;a&lt;/sup&gt;</td>
<td>93.17 ± 0.41&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>TBA value (mg/kg)</td>
<td>0.26 ± 0.04&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.46 ± 0.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.47 ± 0.04&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.65 ± 0.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.65 ± 0.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.74 ± 0.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

All values are mean ± standard deviation of three replicates ($n = 30$).

<sup>a</sup> Means within a row with different superscript letters are significantly different ($P < 0.05$).

<sup>b</sup> *Control: pork back fat, T1: olive oil, T2: grape seed oil, T3: corn oil, T4: canola oil, T5: soybean oil.*
According to Woo, Lee, and Kim (1995), cottonseed oil treatment gave significantly higher TBA values than controls with pork back fat. At the end of the refrigerated storage period (day 12) all treatments with vegetable oils resulted in significantly higher (P < 0.05) TBA values when compared to the control. However, the TBA values at the end of the refrigerated storage period (day 12) were significantly higher (P < 0.05) than the initial (day 1) values. In general, lipids undergoing oxidation cause deterioration and decreased shelf life of meat products (Brewer & Wu, 1993) and, therefore, the greatest disadvantage of using vegetable oils in meat products is potential rancidity development (Yildiz-Turp & Serdaroglu, 2008).

3.3. Cholesterol content and fatty acid composition

Table 3 shows the cholesterol content and fatty acid composition of the reduced-fat frankfurters. Vegetable oil and rice bran fiber containing reduced-fat frankfurter samples had significantly lower cholesterol contents than the control samples at 69.69 mg/100 g. The cholesterol content of the different reduced-fat frankfurters was between 35.40–38.03 mg/100 g. The cholesterol content of reduced-fat frankfurters decreased by 45–50% compared to the control. Vegetable oil and rice bran fiber treatments with pre-emulsified hazelnut oil, Muguera, Gimeno, Ansorena, Bloukas, and Astiasaran (2001) also investigated the effects of replacing pork back fat with pre-emulsified olive oil on fermented sausage. These results agree with those reported by Kayaardi and Gok (2003) who found more cholesterol in animal fat than vegetable oil meat products. American Heart Association (2004) have recommended less than 300 mg cholesterol per day, as high intakes relate to cardiovascular and coronary heart diseases.

In all the treatments, palmitic acid (C 16:0) and stearic acid (C 18:0), oleic acid (C 18:1 cis), and linoleic acid (C 18:2 cis) were more plentiful than other fatty acids. Calculated fatty acid compositions show that the substitution of pork back fat with vegetable oils reduced the percentage of saturated fatty acids (SFA) from 32.9% in the controls to 20.1–24.4% in the reduced-fat frankfurters (Table 3). Thus, the total reduction in SFA was 25–35%. The total amount of MUFA (monounsaturated fatty acids) ranged from 37.0% to 64.6%, and those with olive oil (T1) had the highest total MUFA. These results are similar to the findings of Paneras and Bloukas (1994) who replaced pork back fat with vegetable oils to produce reduced-fat frankfurters. The highest PUFA (polyunsaturated fatty acids) level was in the grape seed oil (T2) and corn oil (T3) samples. The frankfurters containing olive and grape seed, and canola oil showed the highest amount of total UFA (unsaturated fatty acids). Abraham, Riemerssma, Wood, Elton, and Oliver (1989) showed that PUFA reduces plasma cholesterol levels, lowers blood pressure and prevents cardiac arrhythmias. The SFA/UFA ratios for all the vegetable oil treatment samples were significantly lower than those for the control with no added vegetable oil. The lowest SFA/UFA ratio was in the canola oil treatments (T4) samples. Tsanev, Russева, Rizов, and Dontcheva (1989) reported that the reduction in the SFA/UFA ratios due to the incorporation of vegetable oils indicated an improvement in nutritional content. Yildiz-Turp and Serdaroglu (2008) reported that replacing beef fat with 50% hazelnut oil significantly decreased the SFA/UFA ratios. When vegetable oils and rice bran fiber replaced some of the pork fat in reduced-fat frankfurters, the PUFA/SFA ratio was higher than the controls, and among treatments, the grape seed oil treatment had the highest ratios. According to recommendations by British Department of Health (1994) and Wood et al. (2003), whole diets should have a PUFA/SFA ratios higher than 0.45.

The total TFA (trans-unsaturated fatty acids) were lower (P < 0.05) in frankfurters containing olive (T1) and grape seed oil (T2) than in the control samples. The highest amount of total TFA

Table 3

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Control</th>
<th>Treatmentsa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cholesterol (mg/100 g)</td>
<td>69.69 ± 2.95</td>
<td>38.03 ± 1.87a</td>
</tr>
<tr>
<td>Fatty acids composition (g/100 g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capric C10:0</td>
<td>–</td>
<td>2.30 ± 0.11b</td>
</tr>
<tr>
<td>Mirtistic C14:0</td>
<td>1.42 ± 0.31a</td>
<td>0.72 ± 0.21b</td>
</tr>
<tr>
<td>Palmitic C16:0</td>
<td>23.33 ± 0.84a</td>
<td>15.21 ± 0.73c</td>
</tr>
<tr>
<td>Palmitoleic C16:1</td>
<td>3.06 ± 0.23a</td>
<td>1.41 ± 0.13c</td>
</tr>
<tr>
<td>Margaric C17:0</td>
<td>0.43 ± 0.12a</td>
<td>0.25 ± 0.19a</td>
</tr>
<tr>
<td>Margaroleic C17:1</td>
<td>0.46 ± 0.15a</td>
<td>0.23 ± 0.05</td>
</tr>
<tr>
<td>Stearic C18:0</td>
<td>10.67 ± 0.62a</td>
<td>7.25 ± 0.34a</td>
</tr>
<tr>
<td>Oleic C18:1 cis</td>
<td>0.75 ± 0.13a</td>
<td>0.56 ± 0.10b</td>
</tr>
<tr>
<td>Linoleic C18:2 cis</td>
<td>46.15 ± 1.58b</td>
<td>34.89 ± 1.33a</td>
</tr>
<tr>
<td>Linolenic C18:2 cis</td>
<td>14.37 ± 0.82a</td>
<td>38.26 ± 1.99a</td>
</tr>
<tr>
<td>Linolenic C18:3 cis</td>
<td>–</td>
<td>0.60 ± 0.13a</td>
</tr>
<tr>
<td>Linolenic C19:3 cis</td>
<td>0.75 ± 0.13a</td>
<td>0.88 ± 0.07b</td>
</tr>
<tr>
<td>Arachidic C20:0</td>
<td>–</td>
<td>0.32 ± 0.07a</td>
</tr>
<tr>
<td>Gadoleic C20:1</td>
<td>0.95 ± 0.13a</td>
<td>0.32 ± 0.11b</td>
</tr>
<tr>
<td>SFA</td>
<td>35.86 ± 1.86a</td>
<td>22.90 ± 1.31b</td>
</tr>
<tr>
<td>MUFA</td>
<td>51.38 ± 2.31b</td>
<td>37.46 ± 1.92b</td>
</tr>
<tr>
<td>PUFA</td>
<td>15.12 ± 1.29a</td>
<td>32.53 ± 1.82b</td>
</tr>
<tr>
<td>TFA</td>
<td>0.75 ± 0.19a</td>
<td>1.23 ± 0.09b</td>
</tr>
<tr>
<td>SFA/UFAs</td>
<td>0.54a</td>
<td>0.30bc</td>
</tr>
<tr>
<td>PUFA/UFAs</td>
<td>0.42b</td>
<td>1.00a</td>
</tr>
</tbody>
</table>

All values are mean ± standard deviation of three replicates (n = 30).

Means within a row with different superscript letters are significantly different (P < 0.05).


a Control: pork back fat, T1: olive oil, T2: grape seed oil, T3: corn oil, T4: canola oil, T5: soybean oil.
was in the corn oil (T3) samples and the lowest in the grape seed oil (T2) samples. According to Yilmaz (2004), the range of TFA in several foods containing animal and dairy fats from ruminants was 1.5–10.6%, and in pork and beef sausages and other meat products was below 1%. Yilmaz and Dag˘liog˘lu (2003) noted that adding oat bran to meat products decreased the total TFA compared to controls.

3.4. Sensory evaluation

Table 4 shows the results of sensory evaluation for the addition of rice bran fiber and the replacement of pork back fat by various vegetable oils in frankfurters. Each sample was evaluated in terms of color, flavor, juiciness, tenderness and overall acceptability. The control samples had the highest color scores, while the vegetable oil samples had lower (P < 0.05) scores. The flavor, tenderness, and juiciness scores were higher in the controls, but there were no significant (P > 0.05) differences between the control and the treatments. In contrast, the overall acceptability scores were significantly different among the samples. Frankfurters containing soybean oil (T5) had a lower (P < 0.05) overall acceptability than the control and other samples and this may be related with its high TFA value. Similar results were obtained by Vural et al. (2004) and Muguerza, Ansorena, and Astiasaran (2003). Tan, Aminah, Zhang, and Abdul (2006) noted that to produce frankfurters as good as those containing animal fat, restriction of vegetable oil in the total fat blend is needed. According to Liu et al. (1991), meat products manufactured with corn or palm oil were not different in overall acceptability from those manufactured with animal fat. Also, Choi, Jeong, et al. (2008) reported that sausage containing rice bran fiber had higher sensory scores for juiciness and tenderness than controls. Reduced-fat sausages containing vegetable oil generated evaluation scores similar to the high-fat sausage.

4. Conclusions

Commercially available vegetable oils, such as olive, grape seed, corn, canola and soybean oils and rice bran fiber were used as substitutes for pork back fat in the production of reduced-fat frankfurters. The pH and cooking yields of reduced-fat frankfurters were higher (P < 0.05) in the samples formulated with vegetable oil and rice bran fiber than the controls. Reduced-fat frankfurters would be beneficial for health since they have lower total fat, energy, cholesterol content and saturated fatty acid levels. The types of vegetable oil affected the fatty acid composition. The reduced-fat frankfurters formulated with vegetable oil combined with rice bran fiber had overall acceptability similar to regular-fat frankfurters. Thus, the addition of various vegetable oils and rice bran fiber can contribute to the development of reduced-fat frankfurters with desirable quality characteristics.

Acknowledgements

This research was supported (20080201-033-066-001-01-00) by the Rural Development Administration (Republic of Korea). The authors also partially supported by the Brain Korean 21 (BK 21) Project from Ministry of Education and Human Resources Development.

References


J.Y. Choi et al. / Meat Science 84 (2010) 557–563

Table 4

Sensory properties of reduced-fat frankfurters formulated with various vegetable oils and rice bran fiber.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Control</th>
<th>Treatmentsa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
<td>T2</td>
</tr>
<tr>
<td>Color</td>
<td>8.63 ± 0.52a</td>
<td>7.75 ± 0.46b</td>
</tr>
<tr>
<td>Flavor</td>
<td>8.13 ± 0.64</td>
<td>7.75 ± 0.46</td>
</tr>
<tr>
<td>Tenderness</td>
<td>8.50 ± 0.53</td>
<td>8.00 ± 0.53</td>
</tr>
<tr>
<td>Juiciness</td>
<td>8.38 ± 0.52</td>
<td>8.13 ± 0.35</td>
</tr>
<tr>
<td>Overall acceptability</td>
<td>8.50 ± 0.53</td>
<td>8.15 ± 0.53</td>
</tr>
</tbody>
</table>

All values are mean ± standard deviation of three replicates (n = 30).

a,b Means within a row with different superscript letters are significantly different (P < 0.05).


