Effect of Roasting Temperature and Time on the Chemical Composition of Rice Germ Oil

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\textbf{ABSTRACT:} Compositional changes of rice germ oils prepared at different roasting temperatures (160–180°C) and times (5–15 min) from rice germ were evaluated and compared with those of unroasted rice germ oil. The color development and phosphorus content of oils increased significantly as roasting temperature and time increased, whereas the FA compositions of rice germ oils did not change with roasting temperature and time. Four phospholipid classes, i.e., PE, PI, PA and PC, were identified. PE had the lowest stability under roasting conditions. There were no significant differences in \(\gamma\)-oryzanol levels of rice germ oils prepared at different roasting temperatures and times. Four tocopherol isomers \((\alpha-, \beta-, \gamma-, \text{and} \delta\)-tocopherol) and three tocotrienol isomers \((\alpha-, \gamma-, \text{and} \delta\)-tocotrienol) were identified, but no \(\beta\)-tocotrienol was detectable. The content of \(\alpha\)- and \(\gamma\)-tocopherol in rice germ oil gradually increased as roasting temperature and time increased.


\textbf{KEY WORDS:} \(\gamma\)-Oryzanol, phospholipid, phosphorus, rice germ oil, roasting, tocopherol, tocotrienol.

Rice germ is a by-product of the rice milling process which is included in rice bran. In addition rice germ, which is produced by sieving and vibrating the rice bran, has a higher oil content (30\%) than rice bran does (18\%) (1). Because rice germ accounts for 20\% or more of the weight of rice bran, the removal of rice germ can affect the oil content of rice bran (2).

Recently, rice germ oil has been used in Korea as a condiment oil along with sesam oil and perilla oil. Traditionally, these condiment oils are prepared by extracting the roasted seed with a mechanical press or expeller after the seeds have been roasted at the appropriate temperature and for the appropriate time (3,4). During the roasting process, a pleasant aroma or taste (nutlike or peanut butter-like) that transfers to the oil during extraction is developed. The conventional method for preparation of condiment oils such as sesame oil, perilla oil, and red pepper oil involves cleaning, roasting, grinding, and pressing but not refining (5). The roasting process is the key step for making condiment oil since the color, composition, and quality of the oil are all influenced by the conditions of the process. Some researchers (6,7) reported that the chemical composition of an oil is independent of the roasting temperature used for preparing it. However, to our knowledge, little investigation has been conducted on the effects of roasting on the chemical composition of rice germ oil.

The objective of this study was to investigate changes in color, FA composition, and minor components, such as phosphorus, tocopherol, tocotrienol, \(\gamma\)-oryzanol and phospholipids, of rice germ oil roasted at different temperatures and times.

\textbf{EXPERIMENTAL PROCEDURES}

\textit{Rice germ and reagents.} Rice germ used in this study was obtained from Kimpo Agricultural Cooperative Federation (Kimpo, Korea). Tocopherol isomers were purchased from Merck (Darmstadt, Germany) and tocotrienol isomers from Calbiochem (Calbiochem-Novabiochem Co., San Diego, CA). Phospholipid standards were purchased from Sigma Chemical Company (St. Louis, MO). Other chemicals used in this study were analytical grade.

\textit{Preparation of rice germ oil.} Rice germ (200 g) was roasted in an electric roaster equipped with a stirrer and a temperature controller. Rice germ was roasted with constant stirring at 160, 170, and 180°C for 5, 10, and 15 min, respectively. After roasting, the roasted rice germ was allowed to cool to ambient temperature. The roasted rice germ was then pressed (600 kg/cm\(^2\)) using a mechanical press (Carver Inc, Wabash, IN) to obtain the rice germ oil. Unroasted rice germ oil was prepared by the same procedure as described above but without roasting. The extracted rice germ oils were filtered to remove particles.

\textit{Determination of color development.} As an index of color development (8), the absorbance at 420 nm of a 5.0\% (wt/vol) solution of oils in chloroform was determined with a spectrophotometer (UV-900; JASCO, Tokyo, Japan).

\textit{FA composition.} Oils were esterified according to AOCS standard method Ce 2-66 (9). Methyl esters of FA were extracted with hexane. Then 1 \(\mu\)L aliquots of the extracts were injected into a gas chromatograph (Varian 3800; Varian Inc., Walnut Creek, CA) equipped with an FID. The column used was a Supelcowax 10 fused-silica capillary column (30 m \(\times\) 0.32 mm i.d.; Supelco, Bellefonte, PA). The carrier gas was helium, and the total gas flow rate was 20 mL/min. The

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RESULTS AND DISCUSSION

Color development. Color formation in the oil was influenced by the extent of roasting. Color development of rice germ oil prepared at different roasting temperatures and times is shown in Figure 1. With an increase in roasting time and temperature, browning substances were developed, resulting in a significant \( P < 0.05 \) increase of the absorbance at 420 nm. The formation of browning substances in several thermally processed foods results from Maillard-type nonenzymatic reactions between reducing sugars and free amino acid or amide (12).

**FA composition.** The FA composition of an oil can be an indicator of its stability, physical properties, and nutritional value. There were no differences in FA composition of rice germ oils prepared at different roasting temperatures and times (data not shown). Rice germ oil (unroasted) consisted of 0.11% myristic acid, 19.11% palmitic acid, 0.16% palmitoleic acid, 2.04% stearic acid, 35.42% oleic acid, 41.10% linoleic acid, 1.12% linolenic acid, 0.59% arachidic acid, and 0.35% eicosenoic acid. In the case of rice bran oil, the content of oleic acid (41%) was higher than that of linoleic acid (38%) (13). On the other hand, our data showed that the content of linoleic acid (41%) was higher than that of oleic acid (35%) in rice germ oil.

**Phosphorus content and phospholipid distribution.** Phospholipids are integral structure elements of all kinds of membranes in living organisms and are essential for the growth, maturation, maintenance, and functional capacity of cells of the animal and human body (14). The phosphorus contents and
phospholipid distributions determined by HPLC-ELSD for rice germ oils prepared following different roasting temperatures and times are presented in Table 1. There were significant ($P < 0.05$) differences in the phosphorus content of oils prepared at different roasting conditions. With increasing roasting time, phosphorus content significantly ($P < 0.05$) increased. The phosphorus contents of oils prepared from rice germ roasted for 5, 10, and 15 min at 160°C were 220, 272, and 350 ppm, respectively, whereas that of oil prepared from unroasted rice germ was 70 ppm. A similar trend was observed at other roasting temperatures (170 and 180°C). Veldsink et al. (15) reported that the phosphorus content of rapeseed and sunflower oils significantly increased as the preheating temperature of the oilseeds increased. Clark and Snyder (16) also reported that at a higher pretreatment temperature, a larger amount of phosphorus was extracted. Our results confirmed these observations. HPLC chromatograms of phospholipids isolated from rice germ oil prepared at 160°C and different roasting times are shown in Figure 2. Four phospholipid classes—PE, PI, PA, and PC—were identified. The major

### Table 1

**Phosphorus Content and Phospholipid Composition of Rice Germ Oil Prepared by Roasting at Different Temperatures and Times**

<table>
<thead>
<tr>
<th>Roasting temperature (°C)</th>
<th>Roasting time (min)</th>
<th>Phosphorus content (ppm)</th>
<th>Phospholipid classes (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PE</td>
<td>PI</td>
</tr>
<tr>
<td>Unroasted</td>
<td></td>
<td>70.4 ± 0.7^c</td>
<td>32.6 ± 0.8^c</td>
</tr>
<tr>
<td>160</td>
<td>5</td>
<td>220.4 ± 4.2^d</td>
<td>51.9 ± 1.5^d</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>272.9 ± 3.9^e</td>
<td>37.4 ± 1.1^e</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>350.6 ± 4.2^f</td>
<td>10.4 ± 0.7^f</td>
</tr>
<tr>
<td>170</td>
<td>5</td>
<td>232.9 ± 2.3^d</td>
<td>51.6 ± 2.3^d</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>312.5 ± 3.1^d</td>
<td>23.7 ± 0.7^c</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>377.6 ± 1.7^f</td>
<td>1.5 ± 0.2^f</td>
</tr>
<tr>
<td>180</td>
<td>5</td>
<td>262.3 ± 4.1^d</td>
<td>44.9 ± 3.1^d</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>322.7 ± 2.6^e</td>
<td>4.8 ± 0.5^e</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>460.4 ± 1.7^f</td>
<td>ND</td>
</tr>
</tbody>
</table>

*Mean values ± SD of determinations for triplicate samples. Value of the unroasted sample and values in the same column (within the same subgroup) with different superscript letters (c–f) are significantly different ($P < 0.05$) as measured by Duncan’s test. ND, not detected.*

![FIG. 2. HPLC chromatograms of phospholipids isolated from rice germ oils prepared from rice germ roasted for 5, 10, and 15 min at 160°C. Chromatographic conditions: Lichrospher Si-60, 250 × 4.6 mm, 5 µm column (Merck, Darmstadt, Germany); mobile phase, A. chloroform/tertiary-butyl-methyl ether (75:15), B. methanol/ammonium hydroxide/chloroform (92:7:1); linear gradient elution 0 to 100% (B) in 30 min, 10 min at 100% (B), and 0 to 100% (A) in 10 min; flow rate, 0.5 mL/min; detection, evaporative light scattering; peaks: 1, PE; 2, PI; 3, PA; 4, PC.*
phospholipid component of rice germ oil prepared at the shortest roasting time (5 min) was PE. However, the proportion of PE in the rice germ oil decreased significantly \((P < 0.05)\) as roasting time increased. PE in rice germ oil roasted for 15 min at 180°C was completely degraded, suggesting that PE has the lowest stability among phospholipids in rice germ. Previous studies \((17,18)\) have reported that an increase in the roasting temperature and time increased. For example, the contents of α-Tocopherol and tocotrienol homologs in rice germ oil gradually \((P < 0.05)\) increased as roasting temperature and time increased. For example, the contents of α-tocopherol in rice germ oils roasted for 5, 10, and 15 min at 160°C were 1404, 1432, and 1457°F.

**TABLE 2**

<table>
<thead>
<tr>
<th>Roasting temperature (°C)</th>
<th>Roasting time (min)</th>
<th>α-T</th>
<th>β-T</th>
<th>γ-T</th>
<th>δ-T</th>
<th>α-T3</th>
<th>γ-T3</th>
<th>δ-T3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unroasted</strong></td>
<td></td>
<td>1307.6 ± 10.5°C</td>
<td>55.0 ± 1.8°C</td>
<td>115.3 ± 2.5°C</td>
<td>6.8 ± 0.5°C</td>
<td>76.0 ± 1.5°C</td>
<td>49.5 ± 2.1°C</td>
<td>4.4 ± 0.4°C</td>
</tr>
<tr>
<td>160</td>
<td>5</td>
<td>1404.0 ± 8.6°C</td>
<td>54.4 ± 2.2°C</td>
<td>118.8 ± 4.6°C</td>
<td>6.5 ± 0.2°C</td>
<td>76.2 ± 2.0°C</td>
<td>45.2 ± 1.7°C</td>
<td>4.8 ± 0.8°C</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1432.2 ± 9.5°C</td>
<td>57.1 ± 0.8°C</td>
<td>127.2 ± 2.8°C</td>
<td>6.9 ± 0.7°C</td>
<td>76.3 ± 2.3°C</td>
<td>46.2 ± 2.8°C</td>
<td>4.9 ± 0.6°C</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>1457.5 ± 14.3°C</td>
<td>56.6 ± 1.1°C</td>
<td>137.9 ± 3.3°C</td>
<td>6.4 ± 0.6°C</td>
<td>73.6 ± 1.8°C</td>
<td>44.5 ± 3.0°C</td>
<td>4.0 ± 0.7°C</td>
</tr>
<tr>
<td>170</td>
<td>5</td>
<td>1428.7 ± 7.3°C</td>
<td>57.0 ± 2.4°C</td>
<td>121.6 ± 3.7°C</td>
<td>6.3 ± 0.5°C</td>
<td>73.4 ± 0.7°C</td>
<td>46.1 ± 1.5°C</td>
<td>4.4 ± 0.6°C</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1435.9 ± 4.6°C</td>
<td>53.1 ± 0.7°C</td>
<td>135.3 ± 1.5°C</td>
<td>6.4 ± 0.6°C</td>
<td>73.1 ± 2.4°C</td>
<td>43.9 ± 1.6°C</td>
<td>4.2 ± 0.5°C</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>1478.6 ± 12.1°C</td>
<td>56.2 ± 0.9°C</td>
<td>146.6 ± 5.5°C</td>
<td>6.3 ± 0.4°C</td>
<td>74.3 ± 1.4°C</td>
<td>47.4 ± 2.3°C</td>
<td>4.3 ± 0.6°C</td>
</tr>
<tr>
<td>180</td>
<td>5</td>
<td>1445.0 ± 8.6°C</td>
<td>53.6 ± 2.8°C</td>
<td>128.7 ± 4.1°C</td>
<td>6.5 ± 0.3°C</td>
<td>73.2 ± 0.8°C</td>
<td>47.6 ± 2.5°C</td>
<td>4.2 ± 0.7°C</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1468.9 ± 7.9°C</td>
<td>54.5 ± 1.9°C</td>
<td>144.6 ± 3.3°C</td>
<td>6.4 ± 0.8°C</td>
<td>73.6 ± 1.7°C</td>
<td>45.1 ± 0.9°C</td>
<td>4.0 ± 0.1°C</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>1520.2 ± 4.3°C</td>
<td>55.5 ± 3.0°C</td>
<td>160.7 ± 3.2°C</td>
<td>6.7 ± 0.4°C</td>
<td>78.7 ± 2.7°C</td>
<td>48.4 ± 1.7°C</td>
<td>4.3 ± 0.2°C</td>
</tr>
</tbody>
</table>

<sup>a</sup>Mean values ± SD of determinations for triplicate samples.

<sup>b</sup>Abbreviations: T, tocopherol; T3, tocotrienol. Value of the unroasted sample and values in the same column (within the same subgroup) with different superscript letters (a–c) are significantly different \((P < 0.05)\) as measured by Duncan’s test.
mg/kg, respectively, whereas those of α-tocopherol in rice germ oils roasted for 5, 10, and 15 min at 180°C were 1445, 1468, and 1520 mg/kg, respectively. A similar trend was observed in γ-tocopherol. However, there were no significant differences in the content of other tocopherol (β, δ) and tocotrienol homologs (α, γ, and δ) when roasting temperature and time were increased. Yoshida et al. (17) reported that the content of tocopherol in sesame oils prepared by microwave oven heating decreased over time. On the other hand, Yen (25) reported that the level of tocopherol in sesame oils prepared by electric oven heating was increased by roasting temperatures up to 200°C. Lane et al. (26) also reported that a heat pretreatment (over a range of 100–175°C) by a convection oven caused an increase in level and yield of tocopherol in rice bran oil. Moreau et al. (27) offered a possible explanation for the heat-induced increase in the levels of γ-tocopherol in corn hulls, suggesting that a significant amount of γ-tocopherol is bound to proteins or linked to phosphate or phospholipid and that heat breaks these bonds. It is possible that a similar phenomenon occurs in rice germ, in which bonds linking α-tocopherol and γ-tocopherol with phosphate or phospholipid are broken by roasting.

Changes in rice germ oil composition were observed at different roasting temperatures and times, except for FA and γ-oryzanol content. This study is the first report on chemical changes in rice germ oil with roasting temperature and time.

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