Rheological properties, oxidative stability, and tocopherol content during storage of fried dough made with Silky fowl egg: Comparison with hen egg

T. Toyosaki¹

Department of Foods and Nutrition, Koran Women’s Junior College, Fukuoka, 811-1311, Japan

ABSTRACT  Eggs from Silky fowl and White Leghorn hens were used to prepare fried dough. The rheological properties, lipid oxidative stability, and trans, trans-2,4-decadienal and tocopherol content of fried dough made with Silky fowl egg were compared with dough made with hen egg. The fried dough was stored in a glass bottle at 50°C in the dark for 12 d. The fried dough made with Silky fowl egg showed little change in hardness and adhesion for 12 d at 50°C. However, in the fried dough made with hen egg, hardness increased drastically and adhesion decreased. The fried dough made with Silky fowl egg showed restricted generation of hydroperoxides during 12 d in storage at 50°C. In contrast, the fried dough made with hen egg showed an increased amount of hydroperoxides during the 12-d storage. The lowest concentration of trans, trans-2,4-decadienal was observed in fried dough made with Silky fowl egg, whereas the concentration of trans, trans-2,4-decadienal in fried dough made with hen egg was significantly increased. Total tocopherols in fried dough made with Silky fowl egg were degraded 23.3 mg/100 g of fried dough by the end of the experimental period at 50°C. In contrast, total tocopherols in the fried dough made with hen egg were degraded 40 mg/100 g of fried dough. The ratio of unsaturated fatty acids to saturated fatty acids decreased and the hydroperoxide content increased with storage time. The unsaturated fatty acid:saturated fatty acid ratio and hydroperoxide and tocopherol contents were lower in fried dough made with Silky fowl egg than in that made with hen egg, indicating decreased lipid oxidation. The present experiment suggests that the use of Silky fowl egg could improve the rheological properties, oxidative stability, and trans, trans-2,4-decadienal and tocopherol contents of fried dough.

Key words: Silky fowl egg, hen egg, rheological property, oxidative stability, tocopherol

INTRODUCTION

The eggs of the original Silky fowl are well known in Southeast Asia and for thousands of years have been credited with well-known medicinal and health-promoting properties. However, a modern scientific approach has only recently been applied to determine the medicinal, chemical, and biochemical components of Silky fowl eggs (Ferrand and l’Hermite, 1985; Koketsu et al., 1995, 1997, 2003; Sakakibara et al., 2000). We reported that Silky fowl eggs are an excellent food material of processing aid (Koketsu and Toyosaki, 2004; Toyosaki and Koketsu, 2004).

The quality of deep-fried foods deteriorates during storage as a result of oxidation of lipids and depends on the food composition but also on the frying oil (Chang and Perterson, 1978; Sebedio et al., 1987). Compounds such as antioxidants and some thermal and oxidative decomposition reaction products formed in oil during frying are transferred to the food products, affecting their quality (Chang and Perterson, 1978; May et al., 1983; Frankel et al., 1984; Sebedio et al., 1987; Cuesta et al., 1993). The health aspects of thermally oxidized oils and fats are the subjects of ongoing research. The classes of compounds determined to be toxic are the cyclic fatty acid monomers and oxidatively modified triacylglycerols, bearing aldehydic groups that remain in the oil as nonvolatile cleavage products of triacylglycerol alkoxy radicals, produced from normal triacylglycerols during frying. Thermal stressing of cooking oils rich in polyunsaturated fatty acids generates various aldehyde species (i.e., trans-2-alkenals; trans, trans-alka-2,4-dienals; and n-alkanals), species arising from the fragmentation of conjugated hydroperoxy-diene precursors (Gertz, 2000). The above substances are considered responsible for the cytotoxic effects revealed by animal testing (Billek, 2000). The majority of the nonvolatile oxidative by-products are categorized as total polar materials, whereas triacylglycerols in dimeric,
trimeric, or polymeric forms are commonly referred to as polymerized triacylglycerols. *Trans, trans-2, 4-deca-dienal* is produced by the peroxidation of linoleic and arachidonic acid (Esterbauer et al., 1990; Spiteller et al., 2001). *Trans, trans-2,4-deca-dienal* is detected in cooking fumes resulting from heating edible oils such as rapeseed oil, soybean oil, and peanut oil. It is considered to be the major mutagenic and cytotoxic compound in oil fumes (Zhu et al., 2001).

The objective of the current study was to investigate the rheological properties, oxidative stability, and concentrations of *trans, trans-2,4-deca-dienal* and tocopherols in fried dough made with Silky fowl egg as compared with that made with White Leghorn hen egg.

**MATERIALS AND METHODS**

**Materials**

Flour was purchased from Nippon Suisan (Tokyo, Japan). The contents of protein, ash, lipid, and water were 13.1% (Kjeldahl, N × 6.25), 0.4%, 1.8%, and 15.0%, respectively. More than 95% of the flour granules were sifted through a sieve with 132-mm mesh.

Eggs of the Silky fowl and White Leghorn hen were a gift from Canaly 21 (Gifu, Japan). Each fresh egg fraction was obtained from eggs collected within 1 d after being laid and was immediately used in experiments. Eggs were collected from flocks of 20 Silky fowl and 20 hens. A total of 10 batches of fried dough were made, 2 eggs being included in each batch. The same feed was given to the Silky fowl and Leghorns and they were kept under the same environmental conditions.

**Sample Preparation and Storage**

The fried dough formula was as follows: 300 g of flour, 6 g of sodium chloride, 20 g of sucrose, 5 g of linoleic acid (Sigma-Aldrich, St. Louis, MO), 40 g of whole egg, and 60 g of water. The mixture, excluding the egg, was stirred at 25°C and 50 rpm for 20 min, and subsequently, whole egg was added. After further mixing, the dough was fried in 1,000 mL of soybean oil (tocopherol-free) at 210°C for 5 min. The fried dough was placed in a glass bottle and the bottle was tightly screw-capped, wrapped with aluminum foil, and then placed in a 50°C incubator for 12 d. For each type of egg, 5 replicate batches of fried dough were prepared. Each batch of dough was made with 2 eggs, which had been laid by different birds.

**Extraction of Total Lipids from Fried Dough**

Crude total lipids in the fried dough were extracted by the method of Folch et al. (1957). By this method, the total lipid content in fried dough averaged 3.28 g/kg.

**Determination of Fried Dough Rheological Properties**

The hardness and adhesion of the fried dough were measured using a rheometer (TPU-2S, Yamaden Co. Ltd., Tokyo, Japan). The fried dough was placed in a rheometer cell of 42 mm across and 16 mm high. A cylinder-type plunger (diameter of 15 mm) compressed the fried dough in the cell at 5-mm intervals and at a compression rate of 1 mm/s. Quadruplicate replicates were carried out on each sample within 5 min of one another. Each value is expressed as mean ± SD.

**Measurement of Hydroperoxide in Fried Dough**

Oxidative stability was evaluated by the ferric thiocyanate method (Chen et al., 1996) as follows. To the extracted total lipids (50 μL), 75% ethanol (2.35 mL) and 30% HCl (50 μL) were added. After 3 min, the absorbance of the solution was read at 500 nm in a 1-cm cuvette with a UV spectrophotometer (U-2000, Hitachi Co. Ltd., Tokyo, Japan).

**Determination of Total Tocopherols (α, β, and γ) by HPLC**

Total tocopherols (α, β, and γ) were extracted from fried dough as described by Sheehy et al. (1994). Briefly, samples (10 g) were agitated with 500 μL of 25 mM pyrocatechol solution and 10 mL of a saturated methanol solution of potassium hydroxide and were saponified by heating in a water bath at 80°C for 15 min. After saponification, the mixture was mixed with 5.0 mL of n-hexane and 5.0 mL of water, centrifuged, and an aliquot of the upper phase was evaporated to dryness to be further reconstituted in methanol and injected into the HPLC (model 6AV, Shimadzu, Tokyo, Japan). The HPLC was carried out using a reverse phase column (Nucleosil C18, 5 mm, 250 × 4.6 mm column, Waters, Milford, MA) and a mobile phase of methanol:water (97:3, vol/vol) that was delivered in the system at a flow rate of 2 mL/min (Sheehy et al., 1994). Monitoring of the column effluents was performed using a fluorimetric detector set at an excitation wavelength of 290 nm and an emission wavelength of 330 nm. The α-, β-, and γ-tocopherol signals were quantified using peak height and a standard calibration curve.

**Analysis of Fatty Acid Composition**

The fatty acids of the extracted total lipids were converted to methyl esters and analyzed using an Auto-System gas chromatograph (Perkin-Elmer, Pomona, CA) equipped with a split-splitless capillary injector and a flame ionization detector, as described previously (Torres et al., 2002). The sample was separated by a 30 m × 0.25 mm i.d. fused silica column (Rt-2330,
Chromalytic Technology Pty Ltd., Boronia, Victoria, Australia). The flame ionization detector temperature was 250°C. The fatty acid composition was analyzed in duplicate.

**Analysis of Trans, Trans-2,4-Decadienal**

A quantity of frying oil (1 g) was extracted 3 times with HPLC-grade methanol (20 mL) and the extracts were combined. A quantity of fried dough (10 g) was extracted 3 times with HPLC-grade methanol (20 mL) and the extracts were combined. Triplicate methanol extraction of fried dough retained the same quantity of trans, trans-2,4-decadial as the quintuplicate extraction, as proven by HPLC analysis. Aliquots of these solutions were used for the determination of trans, trans-2,4-decadial by gas chromatography-mass spectrometry following the method described previously (Andrikopoulos et al., 2004). A 20-μL aliquot of each methanol extract was injected into the HPLC (model 6AV, Shimadzu). The HPLC was carried out using a mobile phase of water (acidified with phosphoric acid at pH 3.0), methanol, acetonitrile, and 2-propanol, with gradient elution on a Nucleosil C18 120-5 (120 × 4.6 mm) column (Waters) at a flow rate of 1 mL/min. Detection was performed at UV 280 nm. Quantification was performed based on a trans, trans-2,4-decadial standard curve.

**Statistical Analysis**

All data are presented as mean ± SD. Statistical comparison between different treatments was performed by Student’s t-test, which was performed using Duncan’s new multiple range test (Steel and Torrie, 1980) and application software KaleidaGraph Ver. 4.0 (Synergy Software, Reading, PA).

**RESULTS AND DISCUSSION**

**Rheological Properties of Fried Dough**

After 2 d, no changes in hardness and adhesion were observed in either type of fried dough. However, after 4 d, the hardness of the fried dough made with hen egg increased drastically. In contrast, the fried dough
made with Silky fowl egg showed little change in hardness, only increasing in hardness gradually (Figure 1). As for adhesion, the fried dough made with Silky fowl egg decreased drastically after 4 d (Figure 2). The use of Silky fowl egg in the fried dough allowed for its softness and adhesion to be maintained. These results suggest that the physical properties (i.e., egg proteins) of Silky fowl egg are responsible for the network structure of the dough. This mechanism will be examined in detail in the future.

Lipid Oxidation of Fried Dough During Storage in the Dark

Figure 3 shows a comparison of the oxidative stability between fried dough made with Silky fowl egg and that made with hen egg. Hydroperoxidation of fried dough made with Silky fowl egg showed little change during the experimental period. In contrast, the amount of hydroperoxides in fried dough made with hen egg increased drastically during storage. Previously, it was reported that unsaturated fatty acids showed stronger antioxidative activity than saturated fatty acids (Husain et al., 1986; Sugino et al., 1997). We reported that Silky fowl egg showed oxidative stability, owing to its higher ratio of unsaturated fatty acids compared with that of hen egg (Toyosaki and Koketsu, 2004, 2007). The present results are consistent with the previous reports.

From the above results, it can be concluded that the use of Silky fowl egg in fried dough could contribute to maintaining texture and oxidative stability during storage of 12 d.

Total Tocopherol Content in Fried Dough During Storage

Changes in the total tocopherol content of fried dough during 12 d of storage in the dark at 50°C are shown in Figure 4. The total tocopherol content of fried dough showed little change until 4 d in storage and decreased thereafter. The total tocopherol content decrease in the fried dough during storage was higher in fried dough made with Silky fowl egg than in fried dough made with hen egg.
Concentration of Trans, Trans-2,4-Decadienal in Fried Dough During Storage

Figure 5 shows the results of trans, trans-2,4-decadienal concentration in fried dough stored for 12 d in the dark at 50°C. The concentration of trans, trans-2,4-decadienal in fried dough increased slightly during 4 d of storage and increased rapidly thereafter. Dough made with Silky fowl egg and stored for 12 d showed a slight increase in trans, trans-2,4-decadienal concentration. In contrast, the concentration of trans, trans-2,4-decadienal significantly increased in fried dough made with hen egg.

Fatty Acid Composition of Fried Dough During Storage in the Dark

The unsaturated fatty acid:saturated fatty acid ratio of fried dough with Silky fowl and hen egg during storage in the dark at 50°C is shown in Figure 6. The fatty acid composition of fried dough changed during storage; the relative content of capric acid and caprylic acid increased and that of palmitic acid and linoleic acid tended to decrease (data not shown), resulting in a decrease in the ratio of unsaturated to saturated fatty acids. Unsaturated fats are more easily oxidized than saturated fats (Warner and Mounts, 1993; Tyagi and Vasishtha, 1996). Fried dough made with Silky fowl egg showed smaller unsaturated fatty acid:saturated fatty acid ratio changes with storage time. Conversely, fried dough made with hen egg exhibited larger unsaturated fatty acid:saturated fatty acid ratio changes during storage. This indicates that making fried dough with Silky fowl egg is a means for reducing lipid peroxidation during storage in the dark.

REFERENCES


