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Lipid Oxidative Stability of Fried Products Added with Egg Yolk Powder During Storage

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ABSTRACT In this study, we examined the effects of egg yolk powder added to flour dough on the lipid oxidation of fried products during storage. The flour dough containing the egg yolk powder (0, 5, and 10%) was fried in sunflower oil at 180°C for 90 sec. The fried products were then stored at 60°C for 9 days in the dark. The lipid oxidation of the fried products was evaluated by fatty acid composition, peroxide values (POV), conjugated dienoic acid (CDA) contents, and thiobarbituric acid (TBA) values. The color and phospholipids (PL) contents of the fried products were also determined by colorimetry and high performance liquid chromatography, respectively. The addition of egg yolk powder to the dough decreased the POV, CDA contents, and TBA values of the fried products during storage. Although POV, CDA contents, and TBA values significantly increased in the products without egg yolk powder during storage, little change was observed in the products with egg yolk powder. The PL contents remained relatively constant in the fried products added with egg yolk powder during storage. The lightness and greenness of the fried products decreased, and the yellowness increased, as the storage time increased. The results clearly indicate that the addition of egg yolk powder to the dough improved the lipid oxidative stability of the fried products during storage in the dark, and the PL in the egg yolk might have contributed to the improvements in lipid oxidative stability.

KEYWORDS: *egg yolk addition, fried products, lipid oxidation, storage*

INTRODUCTION

Fried snacks have a relatively high level of lipids due to oil absorption during frying. The oxidation products of the oil that are produced during frying can be transferred to the fried products, and affect their storage stability (1). The lipid oxidation of fried products during storage depends on their composition, which is influenced by the frying oil and food materials, as well as by the storage conditions and antioxidants and prooxidants. The addition of food materials such as spinach, carrot, and red ginseng to dough can change the oxidative stability of fried foods during storage (2-4).

Egg consists of egg white (60-63%) and egg yolk (28-29%), and proteins and lipids occupy half of the egg yolk, with a minor portion of carbohydrates and minerals (5). Egg yolk lipids contain neutral lipid (NL, 65%), phospholipid (PL, 30%), and cholesterol (4%). The NL of egg yolk consists of triacylglycerols (55%), monoacylglycerols (14%), and diacylglycerols (14%), with some free fatty acids (6). Phosphatidylcholine (PC, 70-80%), phosphatidyethanolamine (PE, 10-15%), sphingomyelin (SM, 1-3%), and lysophosphatidylcholine (LPC, 1-2%) are components of the egg yolk PL (7-9).

Phospholipids have been reported as prooxidants as well as antioxidants. Phosphatidylcholine decreased the autoxidation of docosahexaenoic acid (10). Also, peroxide formation in the autoxidation of soybean oil at 50°C for 8 weeks was decreased by additions of phospholipids at 0.03 to 0.05% (11). It was suggested that the polar groups in the phospholipids played an important role in their antioxidative effects (12). Phospholipids also act as metal scavengers (13).

Higher amounts of phospholipids can act as prooxidants (14). Phosphatidylcholine (300 ppm) added to purified soybean oil increased the volatile compound formation and oxygen consumption in the oil, possibly by decreasing the surface tension of oil to increase the diffusion rate of oxygen from the headspace to the oil.

Egg yolk is sometimes added to dough in the manufacturing of snacks, for purposes such as nutrient fortification and texture improvement (15). However, the addition of egg yolk may affect the storage stability of final products. When products are manufactured by frying, lipid oxidation can be

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a major factor in determining the storage stability. Therefore, this study was performed to evaluate the lipid oxidation of fried products added with egg yolk powder during storage, as a quality-determining factor.

MATERIALS AND METHODS

Materials and chemicals

Wheat flour (weak flour) and refined, bleached, and deodorized (RBD) sunflower oil were purchased from Daehan Flour Mills Co., Ltd. (Seoul, Korea) and CJ Co. (Seoul, Korea), respectively. The egg yolk powder was a product of SKM Egg Product Export Ltd (Gandhiji Erode, India). Isooctane and acetonitrile were purchased from J.T. Baker (Philipsburg, NJ, USA). BF_3-methanol (14%), PE, PC, and methyl esters of standard fatty acids (palmitic, stearic, oleic, linoleic, and linolenic acids) were acquired from Sigma-Aldrich Co. (St. Louis, MO, USA). Thiobarbituric acid (TBA) reagent was purchased from MTM Research Chemicals (Morecambe, Lancashire, UK). All other chemicals were of reagent grade.

Sample preparation and storage

The egg yolk powder was mixed with wheat flour at weight ratios of 0, 5, and 10 g in 100 g of flour. Distilled water (35 g) was mixed with the mixture (100 g) in a dough mixer (Model 5K5SS, 325 watt; Kitchen Aid, St. Joseph, MI., USA) for 1 min. The dough was then sheeted to 0.2 cm thickness with a pasta maker (Atlas and Pastbike, OMC, Morcato, Italy). Many squares (2 cm × 2 cm) were obtained from the sheets and then fried. One batch of square-shaped dough pieces (50 g) was fried in an electric fryer (Compact Fryer Coolwall HD4292, Philips, Madrid, Spain) holding 2.5 L of sunflower oil at 180°C for 1.5 min, and the same process was continued to obtain approximately 700 g of fried dough for each treatment.

The fried dough pieces were put into 460 mL glass bottles, with 50 g in each bottle, and the bottles were capped, wrapped with aluminum foil, and then stored in an incubator (Model D1-3375, 700 watt; Dong Yang Science, Gyeonggi, Korea) at 60°C for 9 days. All samples were prepared in duplicate. The bottles were taken out after 1, 3, 5, 7, and 9 days of storage for analyses.

Determination of moisture and lipids

The moisture contents of the food materials, including the wheat flour, egg yolk powder, and fried products, were determined with a moisture balance (HA-300, Precisa, Dietikon, Switzerland) at 110°C.

The lipids in the wheat flour, egg yolk powder, and fried products were extracted by the Folch method (16) using a chloroform and methanol mixture (2 : 1, v/v). The fatty acid compositions of the wheat flour, egg yolk powder, sunflower oil, and fried products were determined by gas chromatography (GC) after lipid extraction and esterification with 14% BF_3-methanol (17). A Younglin M600L gas chromatograph (Seoul, Korea) equipped with a flame ionization detector was used, and the column was a Supelcowax 10 capillary column (30 m × 0.53 mm, 1.0 μM thick; Bellefonte, PA, USA). The temperatures of the oven, injector, and detector were 230°C, 270°C, and 280°C, respectively. The nitrogen flow rate was 5 mL/min, and the split ratio was 33 : 1.

The phospholipids (PL) in the wheat flour, egg yolk powder, and fried products were determined by high performance liquid chromatography (1). The lipids extracted by the Folch method were dissolved in chloroform, passed through a polytetrafluoroethylene membrane syringe filter (0.2 μm × 13 mm, National Scientific Co., Lawrenceville, GA, USA), and injected into a Younglin SP 930D HPLC (Anyang, Korea) with a UV detector at 205 nm. The column was a Cosmosil 5SL-II column (4.6 mm × 250 mm; i.d., 5 μm; Nacalai Tesque, Kyoto, Japan), and the eluting solvent was a mixture of acetonitrile, methanol, and phosphoric acid (80 : 20 : 0.35, v/v/v) at 1.5 mL/min. Each PL in the chromatograms was identified by comparing the retention times with those of standard PLs, and quantified with their calibration curves.

Color of fried products

The chromaticity, L (lightness; 0 dark to 100 light), a (+ red ~ – green), and b (+ yellow ~ – blue) values of the fried products was evaluated by a color meter (CR-200, Minolta, Tokyo, Japan), and the color differences between the fried products added with egg yolk powder and the fried products without egg yolk were calculated with the following equation (18), $E^*_{ab} = \{(L^*)^2 + (a^*)^2 + (b^*)^2\}^{1/2}$.

Analysis of lipid oxidation in the fried products during storage

The lipid oxidation of the fried products, during storage at 60°C in the dark, was evaluated by their fatty acid compositions using gas chromatography (17), as well as by peroxide values (POV), conjugated dienoic acid (CDA) content, and TBA values by the AOCS method (19), with Cd 8-53, Ti 1a-64, and Cd 19-90, respectively, after the extraction of the lipid from the fried products by the Folch method.

Statistical analysis

The data were analyzed by one-way analysis of variance (ANOVA) at a 5% significance level for Duncan grouping and regression analysis, using the SAS statistical system (SAS Version 8.2, SAS Inst. Inc, Cary, NC, USA).

RESULTS AND DISCUSSION

Characteristics of food materials and fried products before storage

The wheat flour contained 13.7% moisture and 2.3%

lipid, and the lipid contained palmitic (22.0%), stearic (0.5%), oleic (12.8%), linoleic (63.9%), and linolenic acids (4.0%). A high concentration of linoleic acid in wheat flour was previously reported (20,21). The wheat flour (1 g) contained PE and PC at 0.03 mg and 0.7 mg, respectively. The moisture and lipid contents of the egg yolk powder were 4.8% and 42.2%, respectively. The egg yolk powder lipid consisted of palmitic (26.7%), palmitoleic (8.0%), stearic (7.1%), oleic (45.8%), and linoleic (12.4%) acids. PE and PC were present in the egg yolk powder (1 g) at 71.3 mg and 119.4 mg, respectively, which is similar to the results of a study by Yujie and Shuying (22). The sunflower oil had palmitic (7.1%), stearic (3.5%), oleic (25.1%), and linoleic (64.3%) acids; however, PE and PC were not detected in the oil. RBD oil generally does not contain PL because degumming removes the PL (23).

The compositional characteristics of the egg yolk-added fried products are shown in Table 1. The moisture contents of the fried products, added with egg yolk powder at 0%, 5%, and 10%, were 8.8%, 10.0%, and 11.0%, respectively. The lipid content of the fried product without egg yolk powder was 20.4%, and it consisted of palmitic (7.8%), stearic (3.8%), oleic (25.2%), linoleic (62.8%), and linolenic (0.4%) acids, which was very similar to the fatty acid composition of sunflower oil, a frying medium for manufacturing the fried products. The addition of egg yolk powder to the dough increased the palmitic, stearic, and oleic acid contents of the fried products, and decreased the linoleic acid content. This is due to the higher concentrations of palmitic, stearic, and oleic acid, as well as the lower amount of linoleic acid, in the egg yolk powder as compared to the sunflower oil. The fried products added with egg yolk powder at 10% consisted of palmitic (10.2%), stearic (4.4%), oleic (27.3%), linoleic (57.7%), and linolenic (0.4%) acids.

Although PL was not detected in the fried products without egg yolk powder, the fried products added with egg yolk powder at 5 and 10% contained PE at 5.9 mg/g and 12.3 mg/g, and PC at 0.7 mg/g and 1.6 mg/g, respectively.

The fried products without egg yolk powder showed values of 78.69 for lightness, −3.42 for redness (3.42 for greenness), and 16.77 for yellowness. The addition of egg yolk powder to the dough decreased the lightness and increased the greenness and yellowness. This might be partly due to the carotenoids in the egg yolk, in which contains carotenoids at 9.7 mg/kg (24). The color differences (E*) between the fried products added with egg yolk powder at 5% and 10%, and the fried products without egg yolk, were 5.34 and 11.89, respectively.

Lipid oxidation of the fried products during storage

The lipid oxidation of the fried products during storage at 60°C in the dark, as evaluated by fatty acid compositions, POV, CDA content, and TBA values, is shown in Table 2, Fig. 1, Fig. 2, and Table 3, respectively. The fatty acid compositions of the fried products showed few significant changes with respect to storage time, regardless of the egg yolk powder additions to the dough (Table 2). The content ratio of palmitic to linoleic acid (P/L ratio) in the fried products also remained relatively constant during 9 days of storage in the dark. This means that the additions of egg yolk to the dough did not affect the fatty acid compositions of the fried products during storage.

The POVs of the fried products without egg yolk powder increased with storage time, and were lower than those of the fried products containing egg yolk, which remained relatively constant during 9 days of storage (Fig. 1). This indicates that the egg yolk powder added to the dough inhibited hydroperoxide formation in the lipids of the fried products during storage. It was previously reported that the addition of egg yolk decreased the formation of peroxides in docosahexaenoic acid (DHA) oil during storage at 60°C (25).

The CDA contents of the fried products without egg yolk increased with storage time at 60°C in the dark (Fig. 2), due

Table 1. Characteristics of fried products before storage (Mean ± SD)

	Content of egg yolk powder in dough (%)		
	0	5	10
Moisture content (%)	8.8 ± 0.68	10.0 ± 0.46	11.0 ± 0.39
Lipid content (%)	20.4 ± 1.15	33.2 ± 8.22	30.5 ± 3.95
Fatty acid composition (%)			
C16:0	7.8 ± 0.37	9.0 ± 0.11	10.2 ± 0.03
C18:0	3.8 ± 0.03	4.0 ± 0.08	4.4 ± 0.01
C18:1	25.2 ± 0.01	26.3 ± 0.31	27.3 ± 0.02
C18:2	62.8 ± 0.42	60.2 ± 0.32	57.7 ± 0.08
C18:3	0.4 ± 0.03	0.4 ± 0.02	0.4 ± 0.07
Phosphatidylcholine (mg/g)	nd[1)]	5.9 ± 1.11	12.3 ± 0.58
Phosphatidylethanolamine (mg/g)	nd	0.7 ± 0.15	1.6 ± 0.04

[1)]nd: not detected

Table 2. Effects of egg yolk powder added to dough on the fatty acid compositions of fried products during storage at 60°C in the dark (Mean ± SD)

Egg yolk content (%)	Storage time (days)	Relative Content (%) C16:0	C18:0	C18:1	C18:2	C18:3	P/L[1)]
0	0	7.7 ± 0.41^{ab}	3.7 ± 0.05^{b}	25.1 ± 0.13^{c}	62.5 ± 0.08^{a}	0.4 ± 0.04^{ab}	0.12 ± 0.01^{ab}[2)]
	1	8.1 ± 0.08^{a}	4.2 ± 0.03^{a}	27.2 ± 0.28^{a}	59.6 ± 0.38^{c}	0.5 ± 0.01^{a}	0.14 ± 0.00^{a}
	3	8.1 ± 0.43^{ab}	4.1 ± 0.21^{a}	27.1 ± 1.01^{ab}	59.9 ± 1.94^{bc}	0.5 ± 0.06^{ab}	0.14 ± 0.01^{a}
	5	7.4 ± 0.32^{b}	3.8 ± 0.16^{b}	25.9 ± 0.07^{c}	62.6 ± 0.66^{a}	0.3 ± 0.15^{ab}	0.12 ± 0.01^{b}
	7	7.8 ± 0.05^{ab}	4.0 ± 0.10^{ab}	25.8 ± 0.51^{c}	61.9 ± 0.82^{ab}	0.4 ± 0.05^{ab}	0.13 ± 0.00^{ab}
	9	7.6 ± 0.07^{ab}	3.8 ± 0.05^{b}	25.9 ± 0.24^{bc}	62.6 ± 0.42^{a}	0.3 ± 0.00^{b}	0.12 ± 0.00^{ab}
5	0	9.0 ± 0.10^{a}	4.0 ± 0.08^{ab}	26.2 ± 0.29^{ab}	59.9 ± 0.37^{a}	0.4 ± 0.02^{a}	0.15 ± 0.00^{a}
	1	9.3 ± 0.45^{a}	4.0 ± 0.14^{b}	25.8 ± 0.28^{b}	59.9 ± 0.18^{a}	0.4 ± 0.11^{a}	0.16 ± 0.01^{a}
	3	8.8 ± 0.12^{a}	4.1 ± 0.11^{ab}	26.3 ± 0.14^{ab}	59.9 ± 0.24^{a}	0.4 ± 0.01^{a}	0.15 ± 0.00^{a}
	5	9.1 ± 0.25^{a}	4.1 ± 0.03^{ab}	26.4 ± 0.04^{ab}	59.7 ± 0.10^{a}	0.3 ± 0.10^{a}	0.15 ± 0.00^{a}
	7	9.0 ± 0.05^{a}	4.2 ± 0.10^{a}	26.6 ± 0.43^{a}	59.2 ± 0.60^{a}	0.5 ± 0.11^{a}	0.15 ± 0.00^{a}
	9	9.0 ± 0.09^{a}	4.2 ± 0.01^{a}	26.7 ± 0.28^{a}	59.0 ± 0.65^{a}	0.4 ± 0.04^{a}	0.15 ± 0.00^{a}
10	0	10.1 ± 0.04^{b}	4.3 ± 0.01^{a}	27.1 ± 0.01^{a}	57.2 ± 0.10^{a}	0.4 ± 0.07^{a}	0.18 ± 0.00^{b}
	1	10.9 ± 0.43^{a}	4.3 ± 0.08^{a}	26.9 ± 0.28^{a}	56.2 ± 0.18^{a}	0.4 ± 0.02^{a}	0.19 ± 0.01^{a}
	3	10.2 ± 0.20^{b}	4.3 ± 0.05^{a}	27.3 ± 0.01^{a}	56.9 ± 0.39^{a}	0.4 ± 0.02^{a}	0.18 ± 0.00^{b}
	5	10.5 ± 0.02^{ab}	4.5 ± 0.18^{a}	27.6 ± 0.77^{a}	56.0 ± 0.65^{a}	0.4 ± 0.00^{a}	0.19 ± 0.00^{ab}
	7	10.3 ± 0.11^{b}	4.3 ± 0.07^{a}	27.5 ± 0.63^{a}	56.4 ± 0.90^{a}	0.4 ± 0.01^{a}	0.18 ± 0.00^{ab}
	9	10.3 ± 0.07^{b}	4.4 ± 0.16^{a}	27.5 ± 0.30^{a}	56.4 ± 0.33^{a}	0.4 ± 0.01^{a}	0.18 ± 0.00^{b}

[1)]P/L: Content ratio of palmitic acid to linoleic acid
[2)]Different superscripts indicate a significant difference among samples having the same amount of egg yolk powder within the same column at $\alpha = 0.05$.

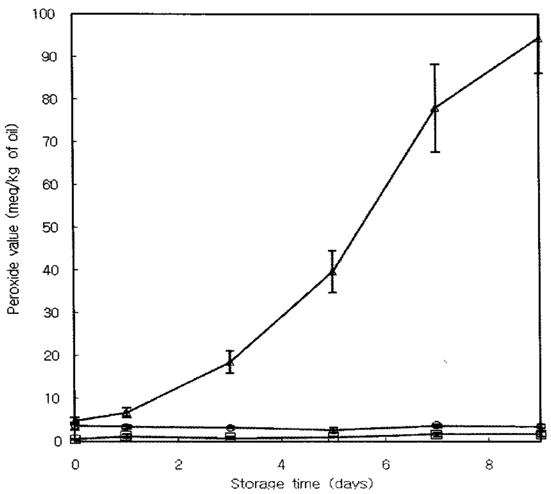

Fig. 1. Effects of egg yolk powder added to dough on the peroxide values of fried products during storage at 60°C in the dark (△: Egg yolk powder added to dough at 0%, ○: 5%, □: 10%).

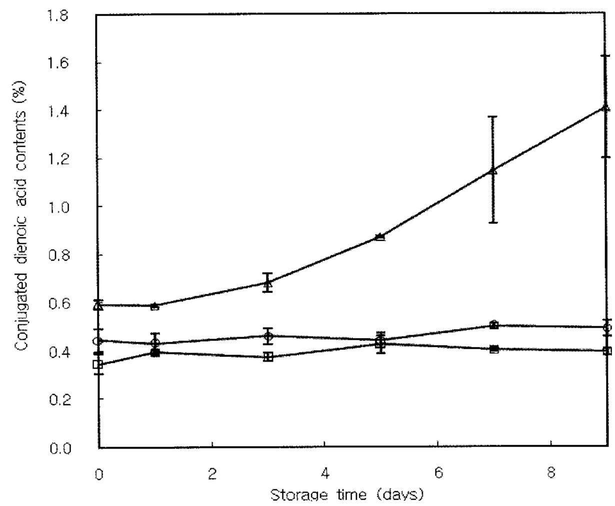

Fig. 2. Effects of egg yolk powder added to dough on the conjugated dienoic acid of the fried products during storage at 60 °C in the dark (△: Egg yolk powder added to dough at 0%, ○: 5%, □: 10%).

to the oxidation of lipids in the fried products. Nonconjugated dienes in lipids are transformed to more stable conjugated dienes by lipid oxidation (26). The CDA contents of the fried products without egg yolk were also significantly higher than those of the fried products added with egg yolk powder. The CDA contents of the fried products added with egg yolk powder showed little change over 9 days of storage. This clearly indicates that the additions of egg yolk powder to the dough significantly decreased lipid oxidation in the fried products during storage.

The TBA value, which tells the secondary oxidation products of lipids by the decomposition of peroxides (27), for the

Table 3. Effects of egg yolk powder added to dough on the thiobarbituric acid values of fried products during storage at 60°C in the dark (Mean ± SD)

Storage time (days)	Thiobarbituric acid value Addition level of egg yolk powder to the flour dough (%) 0	5	10
0	$0.04 \pm 0.00^{bA1)}$	0.03 ± 0.00^{aA}	0.03 ± 0.01^{aA}
1	0.04 ± 0.00^{bA}	0.04 ± 0.01^{aA}	0.04 ± 0.01^{aA}
3	0.04 ± 0.00^{bA}	0.03 ± 0.00^{aA}	0.04 ± 0.01^{aA}
5	0.04 ± 0.00^{bA}	0.03 ± 0.00^{aA}	0.03 ± 0.01^{aA}
7	0.06 ± 0.01^{aA}	0.02 ± 0.01^{aB}	0.02 ± 0.01^{aB}
9	0.07 ± 0.02^{aA}	0.02 ± 0.01^{aB}	0.01 ± 0.01^{aB}

1)Different superscripts of abc and ABC indicate significant differences among samples within the same column and the same row, respectively, at $\alpha = 0.05$.

Table 4. Effects of egg yolk powder to dough on the color of fried products during storage at 60°C in the dark (Mean ± SD)

Color	Storage time (days)	Value Addition level of egg yolk powder to the flour dough (%) 0	5	10
L	0	$78.69 \pm 4.03^{abA1)}$	77.49 ± 3.44^{aA}	77.85 ± 2.90^{aA}
	1	79.57 ± 2.02^{aA}	76.12 ± 2.60^{abB}	75.62 ± 3.66^{abB}
	3	77.71 ± 3.11^{abA}	76.45 ± 19.33^{abAB}	74.34 ± 1.98^{bB}
	5	77.60 ± 3.64^{abA}	74.86 ± 4.91^{abA}	76.07 ± 2.57^{abA}
	7	75.12 ± 2.00^{cA}	73.49 ± 5.60^{bcA}	76.00 ± 3.93^{abA}
	9	76.84 ± 1.72^{bcA}	72.51 ± 1.70^{cC}	74.08 ± 2.51^{bB}
a	0	-3.42 ± 0.29^{cA}	-4.47 ± 0.51^{cB}	-4.75 ± 1.33^{aB}
	1	-3.45 ± 0.18^{cA}	-4.35 ± 0.55^{bcB}	-4.14 ± 0.98^{aB}
	3	-3.09 ± 0.31^{abA}	-3.95 ± 1.29^{abB}	-3.94 ± 0.95^{aB}
	5	-3.16 ± 0.26^{bA}	-3.95 ± 0.68^{abB}	-4.07 ± 0.90^{aB}
	7	-3.06 ± 0.19^{abA}	-3.93 ± 0.52^{abB}	-3.92 ± 1.25^{aB}
	9	-2.95 ± 0.22^{aA}	-3.65 ± 0.76^{aB}	-4.03 ± 0.63^{aB}
b	0	16.77 ± 2.23^{bC}	21.88 ± 2.52^{cB}	28.56 ± 2.27^{aA}
	1	17.54 ± 1.75^{abC}	23.31 ± 2.31^{bcB}	29.04 ± 2.45^{aA}
	3	18.73 ± 2.44^{aC}	25.66 ± 6.33^{abB}	28.22 ± 3.05^{aA}
	5	18.41 ± 2.45^{aC}	25.37 ± 4.06^{abB}	29.01 ± 3.03^{aA}
	7	17.39 ± 2.19^{abC}	25.84 ± 2.59^{aB}	28.43 ± 2.90^{aA}
	9	18.04 ± 1.71^{abC}	25.91 ± 1.82^{aB}	29.73 ± 2.13^{aA}

Different superscript of abc and ABC indicate a significant difference among samples within the same column and the same row, respectively, at $\alpha = 0.05$.

fried products without egg yolk powder, increased from 0.04% to 0.07% after 9 days of storage (Table 3). The TBA values of the fried products added with egg yolk powder were also lower than those of the fried products without egg yolk powder, and did not show significant changes with storage time ($p < 0.05$). This also suggests that the formation of secondary oxidation products in the lipid of the fried products was decreased during storage by the addition of egg yolk to the dough.

The results clearly show that the additions of egg yolk powder to the flour dough improved the oxidative stability of the lipids in the fried product, by decreasing the formation of peroxides, CDA, and secondary oxidation products.

Changes in phospholipid content in the fried products during storage

Figure 3 shows the PL contents of the fried products during storage at 60°C in the dark. The PL contents of the fried products with added egg yolk powder were not significantly different with respect to storage time ($p > 0.05$),

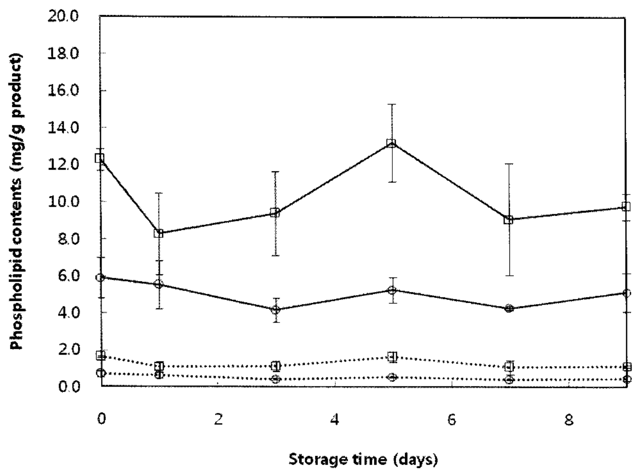

Fig. 3. Effects of egg yolk powder added to dough on the phosphatidylethanolamine (· · · ·) and phosphatidylcholine (—) of fried products during storage at 60°C in the dark (○: Egg yolk powder added to dough at 5%, □: 10%).

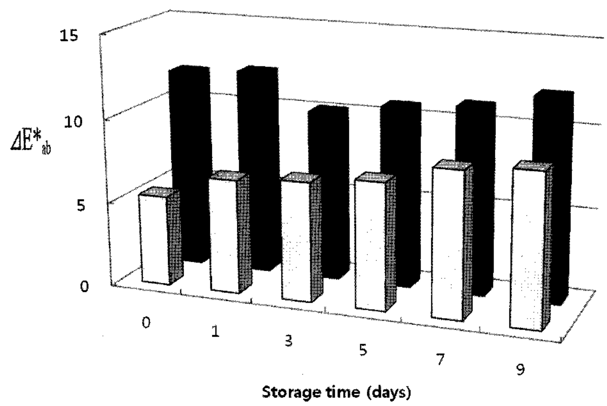

Fig. 4. Effects of egg yolk powder added to dough on the color differences in fried products during storage at 60°C in the dark (□: Egg yolk powder added to dough at 5%, ■: 10%).

indicating the stability of the PL in the fried products during 9 days of storage in the dark at 60°C. The presence of relatively stable PL might have partly resulted in the high oxidative stability of the fried products. The PL in the egg yolk could have partly contributed to decreasing the lipid oxidation of the fried products during storage. The antioxidation of egg yolk phospholipids was reported in the autoxidation of DHA-rich oil and squalene (28). The PL in the egg yolk-added fried products might have reacted with carbonyl compounds produced from lipid oxidation to produce Maillard reaction products, which are known to be antioxidants (29).

Color of fried products during storage in the dark

The color changes of the fried products during storage at 60°C in the dark are shown in Table 4. As the storage time increased, there was a tendency for the lightness and greenness to decrease, and the yellowness and redness to increase. This might be partly due to the formation of brown compounds by the reactions between phospholipids and carbonyl compounds produced during lipid oxidation (1). The color difference between the fried products added with egg yolk at 5%, and the products without egg yolk, increased with storage time (Fig. 4). The fried products added with egg yolk at 10% showed higher color differences from the products without egg yolk as compared to those with 5% egg yolk, which was expected, and their color differences were decreased in the 3 day-stored sample and then re-increased after 5 days of storage.

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