J Korean Soc Appl Biol Chem (2015) 58(4):527–532
DOI 10.1007/s13765-015-0075-1

Online ISSN 2234-344X
Print ISSN 1738-2203

NOTE

Comparison of nutritional quality and thermal stability between peanut oil and common frying oils

Jae Kyeom Kim · Ho-Jeong Lim · Dong-Hoon Shin · Eui-Cheol Shin

Received: 21 January 2015 / Accepted: 21 April 2015 / Published online: 5 May 2015

Abstract The aim of this work was to compare the performances and nutritional characteristics of peanut oil to common frying oils during repetitive frying. The peanut oil had the highest color stability, the lowest initial, and final total polar compounds (TPC) levels among all other oil samples throughout the frying of potato slices. The TPC levels increased in all oils over the course of frying, being impacted more by the initial quality rather than the type of oils. In tocopherol analysis, as a consequence of frying, γ-tocopherol decreased most among the other six tocopherol isomers. Owing to the lack of data on the repetitive frying of peanut oil, this work provides basic information for peanut oil to use for frying purposes.

Keywords Fatty acid · Frying stability · Peanut oil · Tocopherol

Abbreviations

FAME	Fatty acid methyl ester
IV	Iodine value
O/L	Ratio of oleic to linoleic acid
U/S	Ratio of unsaturated to saturated fatty acids
TPC	Total polar compound

J. K. Kim
Department of Food Science and Nutrition, University of Minnesota, Saint Paul, MN 55108, USA

H.-J. Lim · E.-C. Shin (✉)
Department of Food Science, Gyeongnam National University of Science and Technology, Jinju 660-758, Republic of Korea
e-mail: eshin@gntech.ac.kr

D.-H. Shin
Department of Food and Biotechnology, Korea University, Seoul 136-701, Republic of Korea

Introduction

The peanut (*Arachis hypogaea* L.), a plant of the legume family, is native to South and Central America and is widely distributed, mostly as an oilseed crop (Carrín and Carelli 2010). Peanuts contribute significantly to the diet of many cultures and are known as good sources of proteins, lipids, and fatty acids (Grosso et al. 1997). Peanut oil is pale yellow with a nutty taste, while its odor is almost removed by refining processes (Carrín and Carelli 2010).The chemical properties of fats and oils are mostly dependent on fatty acid profiles and positions within the triacylglycerol. The major fatty acids of peanut oil are palmitic (C16:0), oleic (C18:1), and linoleic (C18:2) acids; linolenic acid (C18:3) is present in traces. Therefore, it displays relatively good oxidative stability and is considered an excellent cooking and frying oil. Moreover, peanut breeders have modified the fatty acid profile of peanuts to produce new lines with higher oleic acid content in order to improve the nutritional value and oxidative stability (Ray et al. 1993).

Deep-fat frying is one of the most popular cooking methods because of the desirable flavor, color, and texture of the fried foods (Boskou et al. 2006). However, deep-fat frying is also known to produce undesirable flavor compounds and cause changes in the nutritional quality of oils; hydrolysis, oxidation, and polymerization of fatty acids are common reactions that occur in frying oils. In general, this cooking method decreases the amount of unsaturated fatty acids and increases the amount of free fatty acids, polar materials, and polymeric substances (Choe and Min 2007). However, few reports document the stability of refined peanut oil. The objective of the present study was to provide preliminary data regarding the stability of peanut oil by comparing with other commercially used frying oils (i.e., soybean oil, corn oil, and canola oil) as the consequences of the repetitive frying cycles followed by several measures of oil quality. To be specific, changes in total polar compounds (TPCs), tocopherol (vitamin E) isomers, optical density, and fatty acids profiles were monitored.

Materials and methods

Materials

The oils and potatoes were purchased from local grocery stores (Korea). Prior to analysis, the oil were flushed with N_2 and stored at −40 °C. All high-performance liquid chromatography (HPLC)-grade reagents as well as a lipid standard mixture (37 fatty acid methyl esters (FAMEs) were acquired from Sigma-Aldrich Co. (USA). Other chemicals were of analytical grade.

Frying protocol

White potatoes (200 g) sliced with a fry cutter were fried at 180 °C in a deep-fat fryer (KFR 1301, Kaiser Korea Co., Korea) for 5 min. The frying process was repeated up to 20 times, with one frying cycle per day. After each frying cycle, part of the used oil was removed for analysis, and fresh oil was added to maintain a constant oil volume in the fryer.

Measurement of oil absorbance

Each oil sample was transferred to a microplate with the temperature maintained at 40 °C for 30 min. The absorption spectrum (350–650 nm) of each sample was measured using a spectrophotometer (Multiskan Go; Thermo-Fisher Scientific Co., Finland) to determine the maximum absorption wavelength. In our preliminary test (data not shown), the maximal absorption wavelength was 400 nm; therefore, the color stability was determined at 400 nm.

Measurement of TPC

Testo probe (TESTO 265; Testo AG, Australia) was used for measuring the TPC. Immediately after frying, the Testo probe was dipped into the oil sample to obtain the percent of TPC ($n = 3$).

Analysis of tocopherols

Frying oil (50 mg) was diluted by dissolving in 50 mL of hexane containing 0.01 % (w/v) butylatedhydroxytoluene and filtered through a syringe filter (Sphaero Q, Netherlands) to obtain the oil extract. Upon extracted, 20 µL sample was injected into an Agilent 1260 HPLC system (Agilent Technology, USA). A normal phase LiChrosorb™ SI 60 column (4 mm × 250 mm, 5 µm particle size; Merck, Germany) was connected to a guard column [LiChroCART™ 4-4 guard column packed with LiChrospher Si 60 (5 µm)] and an isocratic mobile phase consisting 0.85 % isopropanol in hexane with a flow rate of 1.0 mL/min. The excitation and emission wavelengths for quantification of tocopherol isomers were 290 and 330 nm, respectively (Shin et al. 2009).

Sample preparation and fatty acid analysis using GC

The FAMEs were prepared according to the literature procedure (Ngeh-Ngwainbi et al. 1997). Upon

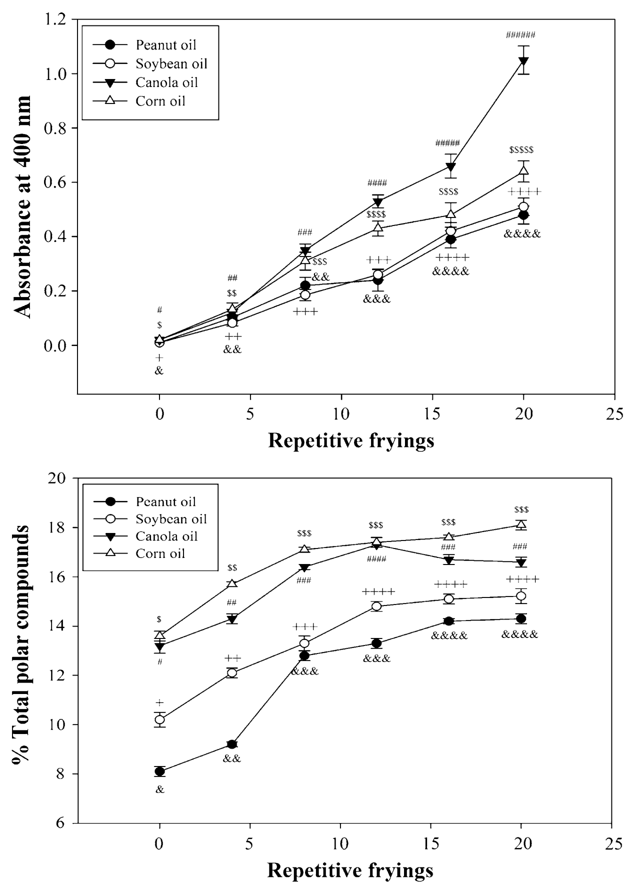

Fig. 1 Measured absorbance at 400 nm (*upper panel*) and TPC levels (*lower panel*) during repetitive frying cycles for the peanut, soybean, canola, and corn oils. Symbols in figure represent different oil sample (canola (*Hash*), soybean (*Plus*), corn (*Dollar*), and peanut (*Ampersand*) oil, respectively). Different numbers of *symbols* indicate the statistical significant between frying cycles in each oil sample ($p < 0.05$). To note, statistical analyses were performed to find effects of a series of frying experiments, not between oil samples. For instance, in the *upper panel*, it was depicted that the absorbance of peanut oil at 400 nm was significantly different in which it underwent 4 frying cycles compared to the original peanut oil given the different numbers of *symbols*

derivatization, an Agilent Technologies 7890A Network GC system with a flame ionization detector was employed for fatty acid analysis. Detailed GC analysis conditions were described elsewhere (Shin et al. 2010). Triplicate readings were taken.

Determination of oil characteristics

The ratio of oleic to linoleic (O/L) acid, iodine value (IV), ratio of unsaturated to saturated fatty acids (U/S), and percentage of saturation (% saturation) were calculated from the fatty acid determinations (Shin et al. 2010).

Statistical analysis

The chemical data obtained from the sample oils have been expressed as the mean ± standard deviation. The statistical significance between the groups was calculated by one-way analysis of variance, followed by the Tukey's multiple range test (SAS, USA). $p < 0.05$ were considered to be statistically significant.

Results and discussion

In order to measure the color stability of oils, samples were subjected to repetitive frying and then analyzed at 400 nm (Fig. 1). Initially, the absorbance of the oil samples was low and did not represent any statistical difference among all other oil samples up to four frying cycles. The color of the oil samples, however, was becoming darker with additional frying, as demonstrated by gradual increase in absorbance. Figure 1 shows the varying extent of change in oil color; at the end of repetitive 20 frying cycles, canola oil showed a deep brown color which is somewhat apparent given the significant changes in absorbance value from the initial condition (i.e., 0 frying). The soybean and peanut oils displayed the least change in color, compared to corn and canola oils ($p < 0.05$). Oil color has been widely used as an index of its quality and is influenced by many factors. In general, oil becomes darker with repeated heating such as frying. Such changes were probably caused by major thermal reactions, including Maillard reaction in cooking oils and thermal degradation of fatty acids at frying temperatures. Other thermal reactions such as non-enzymatic

Table 1 Levels of tocopherol isomers in the sample oils over 20 frying cycles

Oil	Frying cycle	α-T	β-T	γ-T	δ-T	α-T3	γ-T3	Total
Peanut	The 0th	13.00 ± 2.48[a]	0.56 ± 0.13[a]	10.28 ± 0.92[a]	0.77 ± 0.12[a]	0.00 ± 0.00	0.00 ± 0.00	24.60 ± 2.72[a]
	The 4th	12.72 ± 2.51	0.57 ± 0.11	9.90 ± 1.21	0.72 ± 0.22	0.00 ± 0.00	0.00 ± 0.00	23.91 ± 1.73
	The 8th	12.40 ± 1.95	0.52 ± 0.08	9.26 ± 0.83	0.74 ± 0.15	0.00 ± 0.00	0.00 ± 0.00	22.93 ± 2.08
	The 12th	11.08 ± 3.02	0.48 ± 0.09	8.00 ± 0.77	0.64 ± 0.20	0.00 ± 0.00	0.00 ± 0.00	20.20 ± 2.72
	The 16th	10.87 ± 2.62	0.49 ± 0.12	7.43 ± 0.94	0.66 ± 0.13	0.00 ± 0.00	0.00 ± 0.00	19.45 ± 2.12
	The 20th	10.36 ± 2.37[a]	0.44 ± 0.17[a]	6.69 ± 0.74[b]	0.51 ± 0.20[a]	0.00 ± 0.00	0.00 ± 0.00	18.00 ± 2.68[b]
Soybean	The 0th	7.72 ± 1.71[a]	0.90 ± 0.10[a]	63.09 ± 2.72[a]	21.98 ± 1.12[a]	0.00 ± 0.00	0.00 ± 0.00	93.69 ± 4.71[a]
	The 4th	7.64 ± 1.12	0.89 ± 0.08	60.67 ± 2.87	21.31 ± 1.33	0.00 ± 0.00	0.00 ± 0.00	90.51 ± 4.01
	The 8th	7.35 ± 0.96	0.85 ± 0.09	58.30 ± 3.28	20.79 ± 1.72	0.00 ± 0.00	0.00 ± 0.00	87.29 ± 4.14
	The 12th	7.06 ± 1.22	0.89 ± 0.09	55.59 ± 3.74	20.12 ± 1.14	0.00 ± 0.00	0.00 ± 0.00	83.66 ± 5.10
	The 16th	6.55 ± 1.71	0.82 ± 0.12	52.50 ± 2.97	19.86 ± 0.89	0.00 ± 0.00	0.00 ± 0.00	79.73 ± 4.14
	The 20th	6.09 ± 1.74[a]	0.78 ± 0.13[a]	47.70 ± 3.75[b]	18.67 ± 0.92[b]	0.00 ± 0.00	0.00 ± 0.00	73.24 ± 4.72[b]
Canola	The 0th	15.91 ± 1.22[a]	0.00 ± 0.00	28.52 ± 2.12[a]	0.70 ± 0.09[a]	0.00 ± 0.00	0.00 ± 0.00	45.13 ± 3.73[a]
	The 4th	15.22 ± 1.15	0.00 ± 0.00	26.98 ± 1.39	0.78 ± 0.08	0.00 ± 0.00	0.00 ± 0.00	42.98 ± 3.25
	The 8th	15.81 ± 0.99	0.00 ± 0.00	27.33 ± 0.99	0.78 ± 0.10	0.00 ± 0.00	0.00 ± 0.00	43.92 ± 2.99
	The 12th	15.34 ± 1.32	0.00 ± 0.00	26.17 ± 1.27	0.79 ± 0.12	0.00 ± 0.00	0.00 ± 0.00	42.30 ± 3.14
	The 16th	14.78 ± 1.25	0.00 ± 0.00	24.99 ± 1.33	0.84 ± 0.07	0.00 ± 0.00	0.00 ± 0.00	40.61 ± 2.97
	The 20th	14.12 ± 1.07[a]	0.00 ± 0.00	23.21 ± 2.08[b]	0.63 ± 0.12[a]	0.00 ± 0.00	0.00 ± 0.00	37.96 ± 3.10[b]
Corn	The 0th	27.09 ± 1.75[a]	0.65 ± 0.07[a]	62.60 ± 3.12[a]	2.47 ± 0.27[a]	2.69 ± 0.22[a]	1.45 ± 0.22[a]	96.95 ± 4.21[a]
	The 4th	26.64 ± 0.92	0.64 ± 0.05	61.04 ± 2.73	2.29 ± 0.31	2.02 ± 0.32	1.28 ± 0.24	93.91 ± 5.02
	The 8th	26.50 ± 1.22	0.61 ± 0.10	59.70 ± 2.99	2.22 ± 0.44	2.15 ± 0.35	1.20 ± 0.24	92.38 ± 4.97
	The 12th	27.68 ± 0.96	0.64 ± 0.08	57.24 ± 2.45	2.26 ± 0.37	1.03 ± 0.22	1.13 ± 0.31	89.98 ± 4.99
	The 16th	25.99 ± 0.87	0.59 ± 0.07	55.31 ± 3.01	2.22 ± 0.38	2.08 ± 0.32	0.97 ± 0.24	87.16 ± 4.28
	The 20th	25.24 ± 1.92[a]	0.59 ± 0.09[a]	53.30 ± 3.18[b]	2.22 ± 0.29[a]	1.80 ± 0.38[b]	0.99 ± 0.13[b]	84.14 ± 4.10[b]

Different letters indicate the statistical significance between the 0th frying and the 20th frying in each oil sample ($p < 0.05$)

Table 2 Changes in fatty acids composition of the oils over 20 frying cycles

Oil	Frying - cycle	Fatty acid composition (% weight)											
		C14:0	C16:0	C16:1	C18:0	C18:1 (n9)	C18:1 (n7)	C18:2	C18:3 (n6)	C20:0	C20:1	C22:0	C24:0
Peanut	The 0th	0.05 ± 0.01^{a}	10.46 ± 0.92^{a}	0.08 ± 0.01^{a}	2.47 ± 0.19^{a}	51.97 ± 1.92^{a}	0.27 ± 0.03^{a}	26.98 ± 1.42^{a}	0.13 ± 0.01^{a}	1.34 ± 0.09^{a}	1.69 ± 0.13^{a}	3.32 ± 0.26^{a}	1.24 ± 0.08^{a}
	The 4th	0.06 ± 0.01	10.75 ± 0.88	0.10 ± 0.01	2.42 ± 0.12	51.38 ± 2.33	0.27 ± 0.02	27.29 ± 1.35	0.13 ± 0.02	1.23 ± 0.12	1.56 ± 0.12	3.09 ± 0.46	1.71 ± 0.10
	The 8th	0.05 ± 0.02	10.53 ± 1.02	0.08 ± 0.02	2.49 ± 0.13	52.48 ± 2.07	0.25 ± 0.02	26.92 ± 1.41	0.12 ± 0.01	1.33 ± 0.08	1.68 ± 0.17	3.08 ± 0.37	0.97 ± 0.06
	The 12th	0.05 ± 0.02	10.44 ± 1.05	0.08 ± 0.00	2.54 ± 0.11	52.34 ± 1.52	0.24 ± 0.03	26.17 ± 1.19	0.11 ± 0.02	1.41 ± 0.04	1.73 ± 0.16	3.41 ± 0.21	1.48 ± 0.07
	The 16th	0.05 ± 0.00	10.56 ± 0.99	0.06 ± 0.01	2.52 ± 0.13	52.59 ± 1.02	0.24 ± 0.02	26.41 ± 1.41	0.12 ± 0.02	1.39 ± 0.09	1.71 ± 0.09	3.20 ± 0.27	1.15 ± 0.05
	The 20th	0.05 ± 0.01^{a}	10.62 ± 1.07^{a}	0.08 ± 0.02^{a}	2.53 ± 0.12^{a}	52.73 ± 2.04^{a}	0.24 ± 0.02^{a}	26.33 ± 1.31^{a}	0.12 ± 0.01^{a}	1.39 ± 0.10^{a}	1.72 ± 0.11^{a}	3.25 ± 0.31^{a}	0.95 ± 0.09^{b}
Soy-bean	The 0th	0.06 ± 0.02^{a}	9.61 ± 0.82^{a}	0.06 ± 0.01^{a}	4.31 ± 0.23^{a}	25.79 ± 1.02^{a}	0.00 ± 0.00	56.42 ± 2.02^{a}	0.13 ± 0.02^{a}	2.76 ± 0.21^{a}	0.36 ± 0.02^{b}	0.29 ± 0.03^{a}	0.20 ± 0.02^{b}
	The 4th	0.06 ± 0.02	9.63 ± 0.77	0.08 ± 0.02	4.33 ± 0.25	25.88 ± 2.02	0.00 ± 0.00	56.29 ± 2.43	0.12 ± 0.02	2.72 ± 0.26	0.37 ± 0.03	0.31 ± 0.02	0.19 ± 0.03
	The 8th	0.07 ± 0.01	9.67 ± 0.84	0.08 ± 0.01	4.31 ± 0.27	25.76 ± 2.11	0.00 ± 0.00	56.34 ± 2.17	0.14 ± 0.03	2.74 ± 0.19	0.37 ± 0.02	0.31 ± 0.02	0.20 ± 0.02
	The 12th	0.07 ± 0.01	9.74 ± 0.99	0.08 ± 0.00	4.34 ± 0.21	25.85 ± 2.31	0.00 ± 0.00	56.12 ± 2.53	0.16 ± 0.02	2.70 ± 0.21	0.39 ± 0.04	0.29 ± 0.03	0.26 ± 0.03
	The 16th	0.07 ± 0.02	9.81 ± 1.02	0.08 ± 0.01	4.61 ± 0.25	26.50 ± 1.20	0.10 ± 0.00	55.07 ± 2.76	0.16 ± 0.02	2.54 ± 0.19	0.47 ± 0.02	0.35 ± 0.04	0.24 ± 0.04
	The 20th	0.08 ± 0.02^{a}	9.83 ± 0.86^{a}	0.08 ± 0.01^{a}	4.49 ± 0.20^{a}	26.34 ± 2.02^{a}	0.00 ± 0.00	55.39 ± 2.25^{a}	0.15 ± 0.03^{a}	2.56 ± 0.20^{a}	0.45 ± 0.03^{a}	0.31 ± 0.03^{a}	0.28 ± 0.02^{a}
Canola	The 0th	0.07 ± 0.01^{a}	4.56 ± 0.41^{a}	0.22 ± 0.02^{a}	2.17 ± 0.13^{a}	60.83 ± 1.40^{a}	3.01 ± 0.12^{a}	19.34 ± 1.04^{a}	7.41 ± 0.42^{a}	0.69 ± 0.06^{a}	1.17 ± 0.10^{a}	0.37 ± 0.03^{a}	0.15 ± 0.01^{a}
	The 4th	0.08 ± 0.02	4.59 ± 0.55	0.24 ± 0.02	2.06 ± 0.11	59.39 ± 2.21	3.16 ± 0.17	20.32 ± 1.53	8.08 ± 0.22	0.62 ± 0.09	1.06 ± 0.11	0.34 ± 0.02	0.07 ± 0.01
	The 8th	0.10 ± 0.01	4.47 ± 0.61	0.22 ± 0.01	2.11 ± 0.13	60.57 ± 1.25	3.02 ± 0.23	19.45 ± 1.29	7.78 ± 0.26	0.70 ± 0.07	1.24 ± 0.10	0.25 ± 0.03	0.10 ± 0.01
	The 12th	0.06 ± 0.00	4.48 ± 0.48	0.21 ± 0.01	2.22 ± 0.10	61.00 ± 1.40	2.91 ± 0.19	19.04 ± 1.56	7.41 ± 0.22	0.75 ± 0.10	1.28 ± 0.08	0.28 ± 0.02	0.36 ± 0.03
	The 16th	0.06 ± 0.02	4.47 ± 0.44	0.23 ± 0.03	2.15 ± 0.12	61.11 ± 1.43	2.77 ± 0.24	19.17 ± 1.28	7.53 ± 0.31	0.74 ± 0.09	1.27 ± 0.12	0.29 ± 0.03	0.21 ± 0.02
	The 20th	0.07 ± 0.01^{a}	4.48 ± 0.52^{a}	0.22 ± 0.03^{a}	2.14 ± 0.11^{a}	61.07 ± 1.20^{a}	3.05 ± 0.13^{a}	19.25 ± 1.43^{a}	7.55 ± 0.22^{a}	0.72 ± 0.08^{a}	1.26 ± 0.09^{a}	0.27 ± 0.03^{b}	0.20 ± 0.01^{a}
Corn	The 0th	0.04 ± 0.01^{a}	10.82 ± 0.66^{a}	0.13 ± 0.02^{a}	1.88 ± 0.10^{a}	28.56 ± 0.80^{a}	0.00 ± 0.00	56.84 ± 2.21^{a}	1.03 ± 0.12^{a}	0.40 ± 0.03^{b}	0.22 ± 0.03^{b}	0.00 ± 0.00	0.00 ± 0.00
	The 4th	0.04 ± 0.00	11.28 ± 0.58	0.13 ± 0.01	1.97 ± 0.11	29.09 ± 0.60	0.00 ± 0.00	55.83 ± 2.13	0.96 ± 0.11	0.42 ± 0.03	0.26 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
	The 8th	0.03 ± 0.01	11.07 ± 0.84	0.12 ± 0.02	2.08 ± 0.12	29.05 ± 0.75	0.00 ± 0.00	55.82 ± 2.46	0.92 ± 0.13	0.52 ± 0.04	0.39 ± 0.03	0.00 ± 0.00	0.00 ± 0.00
	The 12th	0.03 ± 0.00	11.30 ± 0.71	0.12 ± 0.01	2.18 ± 0.10	29.33 ± 0.81	0.00 ± 0.00	55.12 ± 2.21	0.88 ± 0.12	0.58 ± 0.05	0.47 ± 0.04	0.00 ± 0.00	0.00 ± 0.00
	The 16th	0.04 ± 0.01	11.02 ± 0.65	0.13 ± 0.01	2.03 ± 0.11	29.00 ± 0.69	0.00 ± 0.00	56.00 ± 2.58	0.93 ± 0.09	0.49 ± 0.03	0.37 ± 0.03	0.00 ± 0.00	0.00 ± 0.00
	The 20th	0.04 ± 0.01^{a}	11.04 ± 0.70^{a}	0.12 ± 0.01^{a}	2.00 ± 0.13^{a}	28.97 ± 0.87^{a}	0.00 ± 0.00	56.02 ± 2.12^{a}	0.93 ± 0.12^{a}	0.49 ± 0.02^{a}	0.37 ± 0.02^{a}	0.00 ± 0.00	0.00 ± 0.00

Different letters indicate the statistical significance between the 0th frying and the 20th frying in each oil sample ($p < 0.05$)

browning may also be responsible for these color changes (Choe and Min 2007). In the case of frying potatoes, reactions between sugar aldehyde groups and amino acids are also known to produce brown products (Tsaknis and Lalas 2002). However, there is a caveat to note regarding the oil color and its reliability as an indicator of oil quality. Takeoka et al. (1997) questioned whether oil color was a reliable measure of oil quality, given the fact that factors such as the type and amount of food being fried could also significantly influence the color. Therefore, more comprehensive measurements should be made to determine the nutritional quality and stability of oils (Takeoka et al. 1997).

In the analysis of tocopherol levels, the peanut oil sample showed the lowest content of tocopherols followed by canola, soybean, and corn oils (Table 1). The amounts of each tocopherol found in the sample oils, before and after every 4th frying cycle, were also recorded. Notably, α-T was the dominant tocopherol in the peanut oil, whereas γ-T was the most dominant isomer among all other tocopherol isomers in the other oils, which is in agreement with our previous study (Shin et al. 2009). The tocopherol levels greatly decreased following the repetitive frying cycles of all oils; the total tocopherol level decrease was approximately 6.6, 20.5, 7.1, and 12.8 mg/100 g in the peanut, soybean, canola, and corn oils, respectively ($p < 0.05$ for all). Furthermore, of all isomers, the loss of γ-T was recorded the highest than those of the other tocopherol isomers in all oils. Warner and Moser (2009) reported that the initial presence of higher amounts of tocopherol isomers resulted in faster degradation than those present in lesser amounts. Thus, the higher initial amount of γ-T, compared to the other isomers, may explain the faster degradation of this isomer demonstrated in this study (Warner and Moser 2009) (Table 2).

The TPC levels increased in all oils over the course of the study, with the final readings being impacted more by the initial oil quality rather than by the type (Fig. 1).The peanut oil had the lowest initial and final TPC levels, followed by soybean oil, canola oil, and corn oil, respectively. In general, oils with higher unsaturated fatty acid levels tended to produce more polar compounds, which is in agreement with our results given the degree of unsaturation of peanut oil (see the U/S ratio and % saturation; Table 3). Furthermore, other related parameters of peanut oil were also found to be more favorable for oil stability

Table 3 Chemical characteristics of fatty acids in the sample oils over 20 frying cycles

Oil	Frying cycle	O/L	IV	U/S	% Saturation
Peanut	The 0th	1.94 ± 0.02[b]	93.38 ± 0.85[a]	4.30 ± 0.09[a]	18.88 ± 0.32[a]
	The 4th	1.89 ± 0.03	93.33 ± 1.02	4.19 ± 0.10	19.27 ± 0.39
	The 8th	1.96 ± 0.03	93.67 ± 0.94	4.42 ± 0.11	18.46 ± 0.42
	The 12th	2.01 ± 0.02	92.25 ± 0.75	4.18 ± 0.09	19.32 ± 0.38
	The 16th	2.00 ± 0.03	92.86 ± 0.87	4.30 ± 0.07	18.87 ± 0.44
	The 20th	2.01 ± 0.03[a]	92.87 ± 0.93[a]	4.32 ± 0.11[a]	18.78 ± 0.47[a]
Soybean	The 0th	0.46 ± 0.01[a]	120.55 ± 1.54[a]	4.80 ± 0.08[a]	17.24 ± 0.41[a]
	The 4th	0.46 ± 0.02	120.42 ± 1.62	4.80 ± 0.09	17.25 ± 0.39
	The 8th	0.46 ± 0.01	120.43 ± 1.27	4.78 ± 1.00	17.31 ± 0.51
	The 12th	0.46 ± 0.01	120.20 ± 1.68	4.75 ± 0.97	17.40 ± 0.46
	The 16th	0.48 ± 0.02	119.10 ± 1.48	4.68 ± 0.89	17.61 ± 0.49
	The 20th	0.48 ± 0.01[a]	119.45 ± 1.99[a]	4.69 ± 0.94[b]	17.56 ± 0.52[a]
Canola	The 0th	3.30 ± 0.04[a]	108.88 ± 1.25[a]	11.46 ± 1.01[a]	8.02 ± 0.21[a]
	The 4th	3.08 ± 0.03	111.17 ± 1.54	11.90 ± 1.21	7.75 ± 0.24
	The 8th	3.27 ± 0.04	109.88 ± 1.63	11.95 ± 1.07	7.72 ± 0.30
	The 12th	3.36 ± 0.06	108.51 ± 1.55	11.27 ± 1.06	8.15 ± 0.28
	The 16th	3.33 ± 0.04	109.02 ± 2.01	11.62 ± 1.42	7.92 ± 0.27
	The 20th	3.33 ± 0.03[a]	109.33 ± 1.86[a]	12.00 ± 1.31[a]	7.69 ± 0.31[b]
Corn	The 0th	0.50 ± 0.02[a]	126.11 ± 1.02[a]	6.61 ± 0.09[a]	13.14 ± 0.21[b]
	The 4th	0.52 ± 0.01	124.54 ± 1.58	6.29 ± 0.12	13.72 ± 0.24
	The 8th	0.52 ± 0.01	124.44 ± 1.48	6.29 ± 0.11	13.71 ± 0.29
	The 12th	0.53 ± 0.02	123.44 ± 1.89	6.10 ± 0.08	14.09 ± 0.23
	The 16th	0.52 ± 0.02	124.75 ± 1.65	6.37 ± 0.11	13.58 ± 0.24
	The 20th	0.52 ± 0.02[a]	124.78 ± 1.47[b]	6.37 ± 0.10[b]	13.57 ± 0.28[a]

Different letters indicate the statistical significance between the 0th frying and the 20th frying in each oil sample ($p < 0.05$). *O/L* ratio of oleic to linoleic acids, *IV* iodine value, *U/S* ratio of unsaturated to saturated fatty acids and shelf-life (i.e., the O/L ratio and IV; Table 3). It is well accepted that the linolenic acid content is one of the most critical factors related to the frying performance, stability of oil, and flavor of fried foods (Liu and White 1992). For instance, Xu et al. (1999) measured the TPC levels of sunflower oil and high-linolenic canola oil after frying at 190 °C for 80 h. Their work showed that the TPC level in the sunflower oil was much lower than that of the high-linoleic canola oil (44 vs. 47 %). In contrast, low linolenic (2.5 %) canola oil generated a lower amount of free fatty acids and TPC after frying at the same temperature. However, the total tocopherol level was the lowest in the peanut oil, which was an unexpected finding, considering its stability. However, it has been demonstrated that the tocopherol content was not the most decisive factor for frying performance (Aladedunye and Przybylski 2013), given the fact that fatty acid composition may have a more pronounced effect on the TPC production.

In the present study, the nutritional characteristics and performance of common culinary oils before and after repetitive frying were investigated. The peanut oil showed excellent color stability as well as TPC production. This result was presumably favored by its fatty acid profiles, knowing that peanut oil is characterized by its high oleic acid content as well as the low polyunsaturated fatty acid levels. In contrast, the poorest frying performance was shown by canola oil possibly due to the high ratios of saturated fatty acid and the lowest O/L ratios inherent to the oil. Given the limited experimental information on the frying performances of peanut oil, these results may provide some basic information for peanut oil to use for further culinary/research applications of peanut oil.

Acknowledgments This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2014R1A1 A2058119).

References

Aladedunye F, Przybylski R (2013) Frying stability of high oleic sunflower oils as affected by composition of tocopherol isomers and linoleic acid content. Food Chem 141:2373–2378

Boskou G, Salta FN, Chiou A, Troullidou E, Andrikopoulos NK (2006) Content of trans, trans-2,4-decadienal in deep-fried and pan-fried potatoes. Eur J Lipid Sci Technol 108:109–115

Carrín ME, Carelli AA (2010) Peanut oil: compositional data. Eur J Lipid Sci Technol 112:697–707

Choe E, Min DB (2007) Chemistry of deep-fat frying oils. J Food Sci 72:R77–R86

Grosso NR, Zygadlo JA, Lamarque AL, Maestri DM, Guzmán CA (1997) Proximate, fatty acid and sterol compositions of aboriginal peanut (*Arachis hypogaea* L.) seeds from Bolivia. J Sci Food Agric 73:349–356

Liu HR, White P (1992) High-temperature stability of soybean oils with altered fatty acid compositions. J Am Oil Chem Soc 69:533–537

Ngeh-Ngwainbi J, Lin J, Chandler A (1997) Determination of total, saturated, unsaturated, and monounsaturated fats in cereal products by acid hydrolysis and capillary gas chromatography: collaborative study. J AOAC Int 80:359–372

Ray TK, Holly SP, Knauft DA, Abbott AG, Powell GL (1993) The primary defect in developing seed from the high oleate variety of peanut (*Arachis hypogaea* L.) is the absence of Δ12-desaturase activity. Plant Sci 91:15–21

Shin EC, Huang YZ, Pegg RB, Phillips RD, Eitenmiller RR (2009) Commercial runner peanut cultivars in the United States: tocopherol composition. J Agric Food Chem 57:10289–10295

Shin EC, Pegg RB, Phillips RD, Eitenmiller RR (2010) Commercial Runner peanut cultivars in the USA: fatty acid composition. Eur J Lipid Sci Technol 112:195–207

Takeoka GR, Full GH, Dao LT (1997) Effect of heating on the characteristics and chemical composition of selected frying oils and fats. J Agric Food Chem 45:3244–3249

Tsaknis J, Lalas S (2002) Stability during frying of *Moringa oleifera* seed oil variety "Periyakulam 1". J Food Compos Anal 15:79–101

Warner K, Moser J (2009) Frying stability of purified mid-oleic sunflower oil triacylglycerols with added pure tocopherols and tocopherol mixtures. J Am Oil Chem Soc 86:1199–1207

Xu XQ, Tran VH, Palmer M, White K, Salisbury P (1999) Chemical and physical analyses and sensory evaluation of six deep-frying oils. J Am Oil Chem Soc 76:1091–1099