Effects of jupcheong (soaking in syrup) with ginger powder on the lipid oxidation and antioxidant stability of yakgwa (Korean deep-fried confection)

Boyoung Oh¹ · Kyung-Ae Lee² · Eunok Choe¹

Received: 8 July 2018 / Revised: 24 August 2018 / Accepted: 8 September 2018 / Published online: 19 September 2018
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Abstract This study evaluated the effect of jupcheong (soaking in syrup) with/without ginger on lipids and antioxidants of yakgwa (Korean deep-fried confection) during storage. Yakgwa was prepared with a dough consisting of wheat and rice flour (1:1, w/w), sesame oil, and sugar syrup. Shaped dough pieces were consecutively deep-fried in soybean oil at 90 and 150 °C, soaked in syrup with/without ginger powder, and stored at 30 °C in the dark for 8 weeks. Lipid oxidation was evaluated by peroxide and *p*-anisidine values, and antioxidants were determined spectrophotometrically. Jupcheong reduced lipid oxidation and antioxidant degradation during yakgwa storage, and increased stability by jupcheong was higher in lignans or tocopherols than polyphenols. The results suggest that jupcheong especially with ginger could improve the lipid oxidative stability of yakgwa by higher protection of tocopherols and lignans than polyphenols from degradation, and tocopherols were the most important antioxidants in reducing lipid oxidation of yakgwa.

Keywords Yakgwa · Lipid oxidative stability · Antioxidant · Jupcheong · Ginger

Introduction

Yakgwa is a traditional sweet dessert and has been a festival treat in Korea, possibly dating back a 1000 years (Roufs and Roufs, 2014). It has been made with a dough consisting of wheat flour, honey, and sesame oil. The dough is shaped by either pressing into wooden molds or flattened with cut to small pieces and then fried, followed by jupcheong. Jupcheong is a soaking process of fried dough in honey or sugar syrup to give a sweet taste with a soft and moist texture. To reduce oil absorption during frying, wheat flour is partly replaced by glutinous rice flour having small-sized starch granules (Lee, 2006). Despite long history, consumption of yakgwa in Korea was not high with only occasional treats on the traditional holidays, due to consumer preference for abroad sweets (Hyun and Kim, 2005; Lee and Kim, 2014).

Recently global interests on the Korean traditional foods (K-food) have increased, and efforts to go into the world market have been made, especially in case of traditional sweets. Quality characteristics of yakgwa with added garlic (Moon, 2003), (red) ginseng (Jang et al., 2014; Lee et al., 2013), or green tea (Yun and Kim, 2005) to the dough were reported. Since deep-frying is involved in making yakgwa, the most critical factor to determine its quality during preparation and marketing is lipid oxidation. Storage stability of yakgwa was extensively studied in 1990s; effects of frying oil (Min et al., 1985), mulberry or ginger addition to the flour dough (Lee and Park, 1995; Shin et al., 2014), and soaking in sugar syrup or honey (Lee and Park, 1995) on the storage stability of yakgwa were reported. However, most of these studies reported reduced lipid oxidation of yakgwa without relating it with responsible minor compounds derived from ingredients. Yakgwa is distributed and sold at room temperature and its nutritional and

✉ Eunok Choe
eochoe@inha.ac.kr

¹ Department of Food and Nutrition, Inha University,
100 Inha-ro, Namku, Incheon 22212, Korea

² Department of Food and Nutrition, Soonchunhyang
University, Asan, Korea

functional quality related with its ingredients may decrease with time. Although yakgwa is finally prepared after soaking in honey or sugar syrup, previous studies were limited to the addition of health functional food materials to the flour dough not jupcheong syrup. Therefore, this study evaluated the effect of jupcheong with/without ginger on the lipid oxidation and antioxidant contents of yakgwa with rice and wheat flour during storage in the dark at 30 °C for 8 weeks as marketing conditions, to provide basic information for improved storage stability to yakgwa industry.

Materials and methods

Materials and reagents

Glutinous rice flour (Jukamfarm Co. Ltd., Goheung, Korea), wheat flour (CJ Co., Seoul, Korea), sesame oil (CJ Co.), sugar (CJ Co.), ginger powder (Jeonwon Food Co., Gimpo, Korea), Korean distilled and diluted liquor (soju; 18.5% alcohol, Hitejinro Co., Ltd., Seoul, Korea), soybean oil (Samyang Co., Seoul, Korea), starch syrup (> 50% maltose, Sajohaepyo Co., Seoul, Korea), and jocheong from rice (> 40% maltose, Ottogi Co. Ltd., Anyang, Korea) were purchased from a local supermarket in Incheon, Korea.

n-Hexane, water, methanol, propan-2-ol, acetone, ethanol, and toluene in HPLC grade were purchased from the J. T. Baker (Phillipsburg, NJ, USA). Folin-Ciocalteu's phenol reagent, *p*-anisidine, α -, γ -, and δ -tocopherol, gallic acid, and silicic acid were purchased from the Sigma-Aldrich Co. (St. Louis, MO, USA). Bathophenanthroline was purchased from the Alfa Aesar (Ward Hill, MA, USA), and all other chemicals were of analytical grade.

Preparation of yakgwa and storage

Yakgwa was prepared according to the method of Park et al. (2016) with modifications. Dough for yakgwa basically consisted of wheat flour and glutinous rice flour (1:1, w/w). The flours (200 g) and sesame oil (38 g) were rubbed together with hands, and then passed through a 20 mesh sieve. Sugar syrup (50 g) in soju (40 g) was added to the resulting flour and sesame oil mixture, which was then kneaded, sheeted, and cut into squares of $3 \times 3 \times 0.8$ cm (10.14 ± 0.31 g/piece). Sugar syrup was prepared by boiling mixture of sugar (170 g) and water (200 g) for 10 min and then starch syrup (40 g) was added. Square-shaped dough pieces (20 pieces each frying) were slowly fried in an electric fryer (27×8 cm; Haemaru, Bucheon, Korea) with 1 L of soybean oil at 90 °C for 25 min, and then subsequently fried again in soybean oil (1 L) at

150 °C for 5 min. Fried pieces were soaked in jupcheong syrup for 24 h in the dark at room temperature to finish yakgwa preparation. Jupcheong syrup was prepared by boiling jocheong (1500 g) and water (300 g) for 10 min with/without ginger powder (10 g). The average weight of jupcheong was 3.82 g/piece since the weight of one piece before and after jupcheong was 9.98 ± 0.52 and 13.8 ± 0.69 g, respectively.

Four yakgwa pieces were placed in a petri dish (9 cm dia) with a cover and the dishes were tightly wrapped with plastic films and then aluminum foil, which was finally stored in a 30 °C incubator (LBI-250, Daihan Labtech Co., Seoul, Korea) for 8 weeks in the dark.

Evaluation of yakgwa lipid oxidation

Degree of lipid oxidation of yakgwa was evaluated based on peroxide and *p*-anisidine values by the AOCS (2009) method Cd 8-53 and Ti la-64, respectively, after lipid extraction with *n*-hexane (1:5, w/v).

Determination of antioxidant contents of yakgwa and its ingredients

Antioxidants determined included tocopherols, polyphenols, and lignans. Tocopherols of main ingredients of yakgwa (soybean and sesame oils, wheat and rice flours, jocheong, and ginger powder) were determined using HPLC (YL 9100 HPLC, Younglin Co., Anyang, Korea) equipped with a μ -porasil column (3.9×300 mm, 10 μ m i.d., Waters Co., Milford, MA, USA) and a fluorescence detector (G1321A, Agilent 1100 series, Böblingen, Germany) at the wavelengths of excitation 290 nm and emission 330 nm. The eluent was a mixture of *n*-hexane and isopropanol (99.8:0.2, v/v) at 2 mL/min (Lee and Choe, 2009). The content was quantified using calibration curves of standard α -, γ -, and δ -tocopherols ($r^2 = 1.000$). Total tocopherols of yakgwa were determined spectrophotometrically using Erickson and Dunkley method (1964) with some modification after extracting lipids using *n*-hexane described above. Lipids in *n*-hexane were passed through a polypropylene column (1.5×11.5 cm) packed with activated silicic acid. Benzene was applied as an eluting solvent, and the eluent was mixed with bathophenanthroline solution (6.0 mM) and then ferric chloride solution (1.0 mM). Orthophosphoric acid solution (0.1 M) was added after 2 min, and the absorbance was read at 534 nm using a UV-visible spectrophotometer (HP 8453, Hewlett Packard, Wilmington, DE, USA). Quantification was performed with a calibration curve of α -tocopherol ($r^2 = 0.995$).

Total polyphenols were determined according to the method of Maksimovic et al. (2005) with some

modification. Yakgwa or its ingredients were mixed with 80% acetone (1:100, w/v) in a 25 °C water bath (DS-SHWB45, Dongseo Sience Co. Ltd., Seongnam, Korea) for 6 h, followed by centrifugation (H-500R, Kokusan Ensinki Co. Ltd., Tokyo, Japan) at $484\times g$ and 4 °C for 20 min. The Folin-Ciocalteu's phenol reagent was added to the upper layer, and after 3 min saturated sodium carbonate solution and then distilled water were added. The absorbance was read at 725 nm after 1 h using a UV–visible spectrophotometer (HP 8453, Hewlett Packard), and the content was represented as gallic acid equivalent using a calibration curve ($r^2 = 0.999$).

Total lignans of yakgwa and its main ingredients (soybean and sesame oils, wheat and rice flours, jocheong, and ginger powder) were determined spectrophotometrically by the method of Bhatnagar et al. (2015). The lipids were dissolved in a mixture of hexane and trichloromethane (7:3, v/v), followed by reading of absorbance at 288 nm using a UV–visible spectrophotometer (HP 8453, Hewlett Packard). The content was represented as a sesamin equivalent according to the following equation:

$$\% \text{ Lignan (as sesamin)} = (\text{Abs}/W) \times (100/231.1)$$

where *Abs* absorbance at 288 nm, *W* weight (g) of yakgwa lipid in 100 mL of solution.

Statistical analysis

All samples were prepared in duplicates, and each sample was measured twice. Data were statistically analyzed using SAS/PC (SAS 9.2, SAS Institute Inc., Cary, NC, USA) including regression analyses and Duncan's multiple range test at a significance level of 5% as well as determination of means and standard deviations.

Results and discussion

Antioxidant contents of main ingredients of yakgwa

Tocopherol, lignan, and polyphenol contents of soybean and sesame oils, wheat and rice flours, jocheong, and ginger powder are shown in Table 1. Soybean oil contained only tocopherols totally at 1480 mg/kg, which is similar to previous report (Jung and Choe, 2017). Sesame oil contained lower level of tocopherols (532 mg/kg) than soybean oil, however, it contained high amount of lignans (8560 mg/kg as sesamin) with polyphenols (77.7 mg/kg). Polyphenols were present in wheat and rice flours at 288 and 411 mg/kg, respectively. Wheat flour also contained tocopherols at 3.84 mg/kg. Jocheong contained only polyphenols at 407 mg/kg. Ginger powder contained high amount of polyphenols (8460 mg/kg) with tocopherols

(572 mg/kg). Ginger powder was reported to have total phenols at 10.2 to 13.5 g/kg (Ghasemzadeh et al., 2010) and α - and γ -tocopherol at 180 and 28.2 mg/kg, respectively (Titi Tudorancea, 2018).

Lipid oxidation of yakgwa

The peroxide and *p*-anisidine values of yakgwa during storage at 30 °C in the dark are shown in Fig. 1. The values were increased during storage due to production and decomposition of hydroperoxides, resulting from oxidation of yakgwa lipids (Choe and Min, 2009). The peroxide values before storage were not significantly different among yakgwas with different treatments (0.78, 0.88, 0.90 meq/kg for the control yakgwa without jupcheong, jupcheong yakgwa, and ginger jupcheong yakgwa, respectively). This indicated that there was no significant effect of jupcheong on the yakgwa lipid ($p > 0.05$) before storage. However, yakgwa samples showed significant differences ($p < 0.05$) in the peroxide values among another after storage; 3.17, 2.91, 2.42 meq/kg after 8 weeks for the control yakgwa, jupcheong yakgwa, and ginger jupcheong yakgwa, respectively. The *p*-anisidine value of ginger jupcheong yakgwa (5.49) before storage was not significantly ($p > 0.05$) different from that of the control yakgwa (5.24) or jupcheong yakgwa (5.63), however, there was a tendency of high *p*-anisidine values in yakgwas with jupcheong. This could be due to possible presence of aldehydes in jocheong since jocheong-making involves boiling sugar at high temperature (Tomasik, 2016) and ginger. Raw ginger was reported to have predominantly β -citral and (E)-neral which were remained even after boiling (Li et al., 2016). During storage, yakgwas with jupcheong regardless of ginger addition tended to show high *p*-anisidine values, partly resulted from high initial values.

The peroxide and *p*-anisidine values showed high correlations with time during storage at 30 °C for 8 weeks ($r^2 > 0.855$) as shown in Table 2. The peroxide values of the control yakgwa, jupcheong yakgwa, and ginger jupcheong yakgwa were increased at the rates of 0.342, 0.286, and 0.196 meq/kg/week, respectively. The *p*-anisidine values were increased at the rates of 0.392, 0.327, and 0.303/week in the control yakgwa, jupcheong yakgwa, and ginger jupcheong yakgwa, respectively. The rate of lipid oxidation based on the peroxide and *p*-anisidine value increases was significantly lower ($p < 0.05$) in the ginger jupcheong yakgwa than control yakgwa or jupcheong yakgwa. Jupcheong yakgwa showed a tendency of slower lipid oxidation than the control yakgwa. These results clearly indicated that jupcheong improved the lipid oxidative stability of yakgwa, and ginger addition further increased the antioxidant effect of jupcheong. Lee and Park

Table 1 Antioxidant contents (mg/kg) of main ingredients of yakgwa

Antioxidant	Soybean oil	Sesame oil	Wheat flour	Rice flour	Jocheong	Ginger powder
Tocopherols						
α-	182 ± 15.3	ND	0.51 ± 0.02	ND	ND	332 ± 13.1
γ-	700 ± 60.6	532 ± 0.57	3.34 ± 0.01	ND	ND	150 ± 0.82
δ-	600 ± 37.4	ND	ND	ND	ND	90.0 ± 61.2
Total	1480 ± 113	532 ± 0.57	3.84 ± 0.03	ND	ND	572 ± 75.0
Polyphenols						
Lignans (as sesamin)	ND	77.7 ± 0.43	288 ± 0.04	411 ± 1.44	407 ± 34.1	8460 ± 179
Lignans (as sesamin)						
	ND	8560 ± 450	ND	ND	ND	ND

ND not detected

Fig. 1 Effect of jupcheong on the lipid oxidation, based on the peroxide and *p*-anisidine values, of yakgwa during storage at 30 °C in the dark (open circle: control without jupcheong; filled square: jupcheong; filled triangle: ginger jupcheong)

(1995) also reported that jupcheong decreased lipid oxidation due to reduced exposure of yakgwa lipids to the air. The Maillard reaction products in jocheong, an ingredient of jupcheong syrup, is also thought to contribute to the reduced oxidation rate of yakgwa lipids which were formed in a continuous phase surrounding the starch granules, just as shown in cookies (Vieira and Decker, 2016). Addition of ginger juice to wheat flour dough in yakgwa-making was reported to decrease the lipid oxidation (Park, 1997).

Antioxidant contents of yakgwa during storage

Contents of tocopherols, polyphenols, and lignans present in yakgwa were decreased during storage at 30 °C

(Table 3). Tocopherols detected in yakgwa were derived mostly from sesame oil added to flour for dough-making and soybean oil as a frying oil, and lignans were from sesame oil. Polyphenols detected in yakgwa were derived from wheat and rice flours, sesame oil, jocheong, and ginger powder. Before storage, total tocopherol contents of the control yakgwa, jupcheong yakgwa, and ginger jupcheong yakgwa were 23.6, 26.7, and 44.5 mg/kg, respectively. Significantly higher tocopherol content ($p < 0.05$) of ginger jupcheong yakgwa than other yakgwas was resulted from tocopherols derived from ginger. After 8 week storage, tocopherol contents of yakgwas were significantly decreased to 14.2, 74.1, and 53.5% of the initial level of the control yakgwa (3.36 mg/kg), jupcheong

Table 2 Regression analysis between storage time and peroxide values or *p*-anisidine values of yakgwa with/without jupcheong during storage at 30 °C in the dark for 8 weeks

Yakgwa	Regression parameters ^a		
	a	b	<i>r</i> ²
Peroxide value			
Control (no jupcheong)	0.342	0.570	0.933
Jupcheong	0.286	0.617	0.855
Ginger jupcheong	0.196*	0.791	0.948
<i>p</i> -Anisidine value			
Control (no jupcheong)	0.392	5.06	0.955
Jupcheong	0.327	5.63	0.977
Ginger jupcheong	0.303*	5.66	0.943

^aPeroxide value (meq/kg) or *p*-anisidine value = $a \times \text{storage time (weeks)} + b$, r^2 = determination coefficient

*Significant difference in the slope in each attribute between control and jupcheong samples by dummy variable regression analysis ($p < 0.05$)

yakgwa (19.8 mg/kg), and ginger jupcheong yakgwa (23.8 mg/kg), respectively. These results clearly showed that jupcheong reduced tocopherol degradation, and this could be due to decreased exposure of yakgwa lipid to the air. Retention of tocopherols during yakgwa storage at 30 °C for 8 weeks showed high correlations with time ($r^2 > 0.839$). The proportionality constant ('*k*' value) in the regression equations between storage time and tocopherol retention tells how fast the antioxidant disappeared. Degradation rate of tocopherols during 8 week storage was significantly lower ($p < 0.05$) in jupcheong yakgwa (0.038 mg/kg/week), and there was a tendency of slower degradation in the ginger jupcheong yakgwa (0.078 mg/kg/week) than in the control yakgwa (0.205 mg/kg/week). This strongly suggested a protection of tocopherols from degradation by jupcheong during yakgwa storage.

Polyphenols were initially present in the control yakgwa, jupcheong yakgwa, and ginger jupcheong yakgwa at 7.65, 10.9, and 12.1 mg/kg, respectively, and degraded during storage, too. Significantly ($p < 0.05$) higher polyphenol contents of the jupcheong yakgwa with/without ginger were resulted from polyphenols present in jocheong and ginger powder. After 8 weeks, polyphenol contents were 4.05, 5.31, and 8.21 mg/kg in the control yakgwa, jupcheong yakgwa, and ginger jupcheong yakgwa, respectively. Polyphenol retention during storage at 30 °C for 8 weeks tended to be higher in yakgwas with jupcheong, especially with ginger. However, the difference was less than that of tocopherols. This suggested that jupcheong might exert less effect on polyphenol retention than tocopherol retention during yakgwa storage.

Degradation rates of polyphenols were not significantly different ($p > 0.05$) among yakgwas with different treatments, however, there was a tendency of slower degradation in the ginger jupcheong yakgwa (0.040 mg/kg/week) than the control yakgwa (0.091 mg/kg/week) or jupcheong yakgwa (0.092 mg/kg/week). This result also suggested a protection of polyphenols from degradation by jupcheong, especially ginger jupcheong, during yakgwa storage.

Lignan contents were the highest among antioxidants present in yakgwa, and the contents were 750, 734, and 853 mg/kg in the control yakgwa, jupcheong yakgwa, and ginger jupcheong yakgwa, respectively. There was no significant difference ($p > 0.05$) in lignan contents between the control yakgwa and jupcheong yakgwa, however, the ginger jupcheong yakgwa contained significantly ($p < 0.05$) higher content of lignans than other yakgwas. Although no lignans were detected in our ginger powder, it was reported that fresh ginger contains secoisolariciresinol at 0.2 mg/kg (Valsta et al., 2003). Degradation of lignans during storage of yakgwa was not high compared to tocopherols or polyphenols; 71.6, 88.1, and 92.3% of the initial level were remained after 8 weeks in the control yakgwa, jupcheong yakgwa, and ginger jupcheong yakgwa, respectively. Higher retention of lignans compared to tocopherols or polyphenols was reported during frying, too (Marmesat et al., 2010). Lignans were degraded at a significantly lower rate ($p < 0.05$) in the jupcheong yakgwa (0.014 mg/kg/week) and ginger jupcheong yakgwa (0.010 mg/kg/week) than in the control yakgwa (0.034 mg/kg/week). The results strongly suggested high stability of lignans and further improvement of their stability by jupcheong, possibly due to decreased exposure to the air.

It was reported that the antioxidant degradation rate was positively correlated to the antioxidant efficacy (Chimi et al., 1991), and thus faster degradation of tocopherols compared to lignans or polyphenols suggested that tocopherols can act first as antioxidant in the lipid oxidation of yakgwa during storage. High content and stability of lignans could be another possible factor to reduced lipid oxidation of yakgwa with ginger jupcheong. Therefore, the improvement in the lipid oxidative stability of yakgwa with jupcheong was resulted from increased stability of tocopherols and lignans rather than polyphenols. It was reported that α -tocopherol was the most critical minor compound to control lipid oxidative stability of dried laver (Oh et al., 2014).

In conclusion, tocopherols were the most important antioxidant in controlling lipid oxidation of yakgwa, and the storage stability of yakgwa was significantly improved by jupcheong. Ginger addition to jupcheong syrup further increased the lipid stability via protecting tocopherols and lignans from degradation.

Table 3 Antioxidant contents of yakgwa with/without jupcheong during storage at 30 °C in the dark

Storage time (weeks)	Control (no jupcheong)	Jupcheong	Ginger jupcheong
<i>Tocopherols (mg/kg)</i>			
0	23.6 ± 0.27 ^{e1} (100)	26.7 ± 0.48 ^d (100)	44.5 ± 0.16 ^a (100)
2	12.8 ± 0.24 ^g (54.4)	24.8 ± 0.35 ^e (92.8)	33.3 ± 0.18 ^b (74.7)
4	11.7 ± 0.19 ^{gh} (49.5)	23.0 ± 0.30 ^e (86.2)	29.4 ± 0.98 ^c (66.1)
6	10.5 ± 0.06 ^h (44.4)	21.0 ± 0.18 ^f (78.5)	24.0 ± 1.79 ^e (54.8)
8	3.36 ± 0.54 ⁱ (14.2)	19.8 ± 0.65 ^f (74.1)	23.8 ± 2.27 ^e (53.5)
Regression ²			
k	0.205	0.038* ³	0.078
[A] ₀	23.7	26.7	41.3
r ²	0.839	0.996	0.928
<i>Polyphenols (mg/kg)</i>			
0	7.65 ± 0.19 ^{cd1} (100)	10.9 ± 0.10 ^b (100)	12.1 ± 0.13 ^a (100)
2	6.79 ± 0.28 ^e (88.8)	10.7 ± 0.01 ^b (97.9)	12.1 ± 0.36 ^a (99.9)
4	4.27 ± 0.16 ^g (55.79)	7.67 ± 0.22 ^{cd} (70.53)	11.95 ± 0.83 ^a (98.57)
6	3.90 ± 0.34 ^g (51.0)	7.03 ± 0.13 ^{de} (64.6)	11.8 ± 0.23 ^a (97.6)
8	4.05 ± 0.18 ^g (52.9)	5.31 ± 0.03 ^f (48.8)	8.21 ± 0.04 ^c (67.8)
Regression ²			
k	0.091	0.092	0.040
[A] ₀	7.37	11.6	13.1
r ²	0.828	0.944	0.557
<i>Lignans (mg/kg)</i>			
0	750 ± 12.4 ^{bcdel} (100)	734 ± 70.7 ^{def} (100)	853 ± 22.5 ^a (100)
2	672 ± 20.2 ^{efg} (89.6)	714 ± 25.6 ^{defg} (97.3)	850 ± 32.1 ^a (99.7)
4	673 ± 44.4 ^{efg} (89.7)	701 ± 45.9 ^{efg} (95.5)	822 ± 33.5 ^{ab} (96.4)
6	665 ± 40.6 ^{fg} (88.6)	695 ± 35.1 ^{efg} (94.6)	813 ± 7.18 ^{abc} (95.4)
8	537 ± 12.8 ^h (71.6)	647 ± 46.2 ^g (88.1)	787 ± 23.5 ^{abcd} (92.3)
Regression ²			
k	0.034	0.014* ³	0.010* ³
[A] ₀	751	738	859
r ²	0.778	0.887	0.947

Different superscripts mean significant difference among values in each antioxidant by Duncan's multiple rang test at 5%

Estimated by regression assuming first-order kinetics, $\ln([A]/[A]_0) = -k \times \text{storage time (weeks)}$, where [A] and [A]₀ are content of tocopherols, polyphenols, or lignans (mg/kg) at time t and 0, respectively. r²: determination coefficient

*Significant difference in the slope between control and jupcheong samples in each antioxidant by dummy variable regression analysis ($p < 0.05$)

Acknowledgments This research was supported by the Globalization of Korean Foods R&D program, funded by the Ministry of Agriculture, Food, and Rural Affairs, Republic of Korea, for which the authors are grateful.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

References

- AOCS. Official Methods and Recommended Practices of the AOCS. 6th ed. Method Cd 8-53, Ti 1a-64. American Oil Chemist's Society, Champaign, IL, USA (2009)
- Bhatnagar AS, Hemavathy J, Krishna AGG. Development of a rapid method for determination of lignans content in sesame oil. *J. Food Sci. Technol.* 52: 521–527 (2015)
- Chimi H, Cillard J, Cillard P, Rahmani M. Peroxyl and hydroxyl radical scavenging activity of some natural phenolic antioxidants. *J. Am. Oil Chem. Soc.* 68: 307–312 (1991)
- Choe E, Min DB. Mechanisms of antioxidants in the oxidation of foods. *Comp. Rev. Food Sci. Food Saf.* 8: 345–358 (2009)
- Erickson DR, Dunkley WL. Spectrophotometric determination of tocopherol in milk and milk lipids. *Anal. Chem.* 36: 1055–1058 (1964)
- Ghasemzadeh A, Jaafar HZE, Rahmat A. Antioxidant activities, total phenolics and flavonoids content in two varieties of Malaysia young ginger (*Zingiber officinale* Roscoe). *Molecules* 15: 4324–4333 (2010)
- Hyun JS, Kim MA. The effect of addition of level of red ginseng powder on Yackwa quality and during storage. *Korean J. Food Culture* 20: 352–359 (2005)
- Jang OH, Park JH, Kim SH, Lee SY, Moon BK. Quality characteristics of Yackwa with red ginseng marc powder. *Korean J. Food Cook. Sci.* 30: 800–805 (2014)
- Jung L, Choe E. Lipid oxidation-related characteristics of gim bugak (Korean fried cuisine with *Porphyra*) affected by frying oil. *Food Sci. Biotechnol.* 26:623–631 (2017)
- Lee J, Choe E. Effects of phosphatidylcholine and phosphatidylethanolamine on the photooxidation of canola oil. *J. Food Sci.* 74: 481–486 (2009)
- Lee JH, Kim JS. Quality characteristics of Yackwa made with Yam (*Dioscorea batatas* Decne) powder. *Korean J. Culinary Res.* 20: 56–68 (2014)
- Lee JH, Park KM. Effect of ginger and soaking on the lipid oxidation in Yackwa. *Korean J. Food Cook. Sci.* 11: 93–97 (1995)
- Lee KA. Effect of black rice flour replacement on physicochemical, textural and sensory properties of Yackwa. *Korean J. Hum. Ecol.* 15: 669–674 (2006)
- Lee KS, Kim GH, Seong BJ, Kim SI, Han SH, Lee SS, Song MR, Lee GH. Quality characteristics of Yackwa added with ginseng fruit, leaf and root. *J. Korean Soc. Food Sci. Nutr.* 42: 1981–1987 (2013)
- Li JL, Tu ZC, Zhang L, Sha XM, Wang H, Pang JJ, Tang PP. The effect of ginger and garlic addition during cooking on the volatile profile of grass carp (*Ctenopharyngodon idella*) soup. *J. Food Sci. Technol.* 53: 3253–3270 (2016)
- Maksimović Z, Malenčić D, Kovačević N. Polyphenol contents and antioxidant activity of Maydis stigma extracts. *Biores. Technol.* 96: 873–877 (2005)
- Marmesat S, Morales A, Velasco J, Dobarganes MC. Action and fate of natural and synthetic antioxidants during frying. *Grasas Aceites* 61: 333–340 (2010)
- Min BA, Lee JH, Lee SR. Effects of frying oils and storage conditions on the rancidity of Yackwa. *Korean J. Food Sci. Technol.* 17: 114–120 (1985)
- Moon SI. A study of garlic-Yackwa development I. Quality characteristics of garlic-Yackwa substituted with different amounts of garlic juice. *J. Korean Soc. Food Sci. Nutr.* 32: 1285–1291 (2003)
- Oh S, Lee E, Choe E. Light effects on lipid oxidation, antioxidants, and pigments in dried laver (*Porphyra*) during storage. *Food Sci. Biotechnol.* 23: 701–709 (2014)
- Park J-S, Shin M, Choe E, Lee K-A. Sensory characteristics and consumer acceptance of yakgwa with glutinous rice flour. *J. East Asian Soc. Diet. Life* 26: 271–277 (2016)
- Park KM. Studies on the lipid rancidity and rheology of yackwa during storage. *Korean J. Food Cook. Sci.* 13: 609–616 (1997)
- Roufs TG, Roufs KS. Sweet Treats around the World: An Encyclopedia of Food and Culture. ABC-CLIO, Santa Barbara, CA, USA. p. 213 (2014)
- Shin SK, Kim HJ, Kim MR. Effects of mulberry concentrate on lipid oxidation of Yackwa during its storage. *Korean J. Food Preserv.* 21: 483–490 (2014)
- Titi Tudorancea. The Titi Tudorancea Bulletin English edition. Nutrition: Spices, ginger, ground. Available from: https://www.tititudorancea.com/z/nutrition_facts_zingiber_officinale_spices_ginger_ground.htm. Accessed June 06, 2018.
- Tomasik P. Caramel: Methods of manufacture. Vol. 1, pp. 633–635. In: Encyclopedia of Food and Health. Caballero B, Finglas PM, Toldra F (eds). Elsevier, New York, NY, USA (2016)
- Valsta LM, Kilkkinen A, Mazur W, Nurmi T, Lampi AM, Ovaskainen ML, Korhonen T, Adlercreutz H, Pietinen P. Phyto-oestrogen database of foods and average intake in Finland. *British J. Nutr.* 89: Suppl. 1, S31–S38 (2003)
- Vieira SA, Decker EA. Impact of reducing and non-reducing sugars on lipid oxidation in low moisture baked goods. In: Abstracts: 107th AOCS Annual Meeting and Expo. May 1–4, Salt Palace Convention Center, Salt Lake City, Utah, USA. The American Oil Chemists' Society, Urbana, IL, USA (2016)
- Yun GY, Kim MA. The effect of green tea powder on Yackwa quality and preservation. *Korean J. Food Culture* 20: 103–112 (2005)