

Estimated daily per capita intakes of phenolics and antioxidants from coffee in the Korean diet

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Abstract This study evaluated the daily per drinker intakes of total phenolics, total flavonoids, and antioxidants from coffee in the Korean diet. Four types of coffee (instant coffee, decaffeinated instant coffee, roasted coffee, and coffee mix) were selected and analyzed. Based on the Korea National Health and Nutrition Examination Survey in 2012, the daily intakes per coffee drinker were estimated to be 348.6 mg gallic acid equivalents for phenolics, 222.5 mg catechin equivalents for flavonoids, and 370.8 mg vitamin C equivalents (DPPH assay) or 546.7 mg vitamin C equivalents (ABTS assay) for antioxidants. Men had higher intakes of instant coffee and coffee mix, while women had a higher intake of roasted coffee. Regarding age categories, over 58% of the coffee consumers were 30–59 years old. This study revealed that, in Korea, approximately half of the people drank about 1.4 cups of roasted coffee or 2.0 cups of instant coffee every day.

Keywords Coffee drinker · Korea National Health and Nutrition Examination Survey · Total flavonoids · Total phenolics · Vitamin C equivalent antioxidant capacity

Introduction

Coffee is one of the most popular beverages and is widely consumed throughout the world (Je and Giovannucci, 2014). More than 2.25 billion cups of coffee are consumed across the globe every day, with the number continuously increasing (Ponte, 2002). Although there are more than 80 species of coffee beans, the three most commercialized coffee species worldwide are *Coffea arabica*, *C. canephora*, and *C. liberica* (Perfecto et al., 1996). Korean coffee consumption is ranked as 11th in the world (USDA, 2015), which is rather low compared to Western countries, but has sharply increased in recent years.

Coffee is rich in biologically active substances, including antioxidants such as caffeic, chlorogenic, and ferulic acids (Dórea and da Costa, 2005; Higdon and Frei, 2006; Kim and Lee, 2004; Toci et al., 2018; Yashin et al., 2013). The amounts of phenolic acids such as chlorogenic, ferulic, cinnamic, and caffeic acids in commercial coffee products depend on the type and variety of coffee (Belguidoum et al., 2014). Coffee is the major dietary source of chlorogenic acid (Clifford, 1999). Chlorogenic acid has been reported to inhibit the proliferation of lung cancer cells and to suppress the expression of nuclear factor-kappaB, activator protein-1, and mitogen-activated protein kinases mediated by reactive oxygen species (Feng et al., 2005). Caffeic acid has been found to inhibit the oxidation of low-density lipoprotein and induce biological effects in the blood circulation (Olthof et al., 2001). Recent studies have demonstrated that moderate coffee consumption and

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the antioxidant capacity of coffee may improve health and the quality of life by helping to prevent the onset of degenerative diseases (Dórea and da Costa, 2005; Higdon and Frei, 2006).

The markets of the European Union, United States, Brazil, and Japan accounted for approximately 67% of the total coffee consumption in 2013. In the United States, the mean coffee consumption per drinker was approximately 417 mL per day (Loftfield et al., 2016), and in Japan, coffee consumption is around 213 mL/day, making coffee the second most consumed beverage after green tea (Fukushima et al., 2009). An average of daily 2.2 cups per coffee drinker is consumed in the Mediterranean area (Veronese et al., 2018). Coffee may deliver a significant amount of antioxidants to coffee drinkers. The estimated total antioxidant intake from coffee was found to vary from 93 to 129 mmol Fe²⁺/L for the FRAP assay, from 45 to 66 mmol Trolox equivalents/L for the TRAP assay, and from 26 to 36 mmol Trolox equivalents/L for the TEAC assay (Pellegrini et al., 2003). It was reported that American coffee prepared with 10 g of coffee per cup of brew contains an average of 200 mg chlorogenic acid/cup (Richelle et al., 2001). A 200-mL cup of roasted and ground coffee was estimated to supply 20–675 mg of chlorogenic acid (Clifford, 1999), and coffee was found to have 200–550 mg of antioxidants/cup (Yashin et al., 2013).

However, little information is available on daily coffee consumption with respect to the age and gender of consumers. Moreover, studies on the daily per capita intakes of total phenolics, total flavonoids, and antioxidants from coffee in the Korean diet have not been reported. Therefore, in the present study, the total phenolic contents, total flavonoid contents, and antioxidant capacities of 21 commercial brands of various coffee products available in the Korean market were evaluated, including instant coffee, decaffeinated instant coffee, roasted coffee, and coffee mix. Along with these experimental measurements, the daily intakes per drinker of total phenolics, total flavonoids, and antioxidants from coffee were estimated on the basis of the existing dataset of the Korea National Health and Nutrition Examination Survey in 2012 (KNHANES 2012).

Materials and methods

Samples

Various types of commercial coffee products from different brands were purchased from local markets in Yongin, Republic of Korea and analyzed. Twenty-one commercial brands of four types of coffee included 10 kinds of instant coffees (soluble coffee granules), two kinds of decaffeinated instant coffees (decaffeinated soluble coffee

granules), two kinds of roasted coffees (brewing coffee), and seven kinds of coffee mixes (soluble coffee granules with sugar and creamer), called three-in-one coffee or stick coffee. Samples were stored at ambient temperature prior to analysis.

Chemicals

Folin-Ciocalteu's phenol reagent, 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS), 1,1-diphenyl-2-picrylhydrazyl (DPPH), gallic acid, catechin, and ascorbic acid were purchased from Sigma Chemical Co., LLC. (St. Louis, MO, USA). 2,2'-Azobis(2-amidinopropane) dihydrochloride (AAPH) was obtained from Wako Pure Chemical Industries, Ltd. (Osaka, Japan).

Extraction of phenolics

For the preparation of coffee extracts, 1.6 g of instant coffee, 1.6 g of decaffeinated instant coffee, or one stick of coffee mix (about 12 g of pre-mixed coffee stick with creamer and sugar) was mixed with 100 mL of distilled water at 70–80 °C. Roasted ground coffee (20 g) was brewed in a commercial automatic drip coffee maker (Philips HD-7466; Koninklijke Philips Electronics N.V., Amsterdam, Netherlands) with 450 mL of deionized water. All analyses were performed in triplicate.

Determination of total phenolics

The levels of total phenolics in coffee products were determined colorimetrically with Folin-Ciocalteu's phenol reagent (Singleton and Rossi, 1965). Each extract (0.2 mL) was mixed with 2.6 mL of distilled water. An aliquot (0.2 mL) of Folin-Ciocalteu's phenol reagent was added to the mixture. After 6 min, 2.0 mL of 7% (w/v) Na₂CO₃ solution was added to the reaction mixture. After 90 min, the absorbance was measured at 750 nm using a spectrophotometer (Spectronic 200; Thermo Fisher Scientific Inc., Waltham, MA, USA). The total phenolic content was expressed as mg gallic acid equivalents (GAE)/g dry weight (DW) of coffee. Each extract was analyzed in triplicate.

Determination of total flavonoids

The levels of total flavonoids were measured with a modified version of the method of (Jia et al., 1999). Five hundred microliters of coffee extract was mixed with 3.2 mL of distilled water, and 150 µL of 5% (w/v) NaNO₂ was added to the mixture. After 5 min, 150 µL of 10% (w/v) AlCl₃ was added. After 6 min, 1 mL of 1 M NaOH was

added. The absorbance of the mixture was immediately measured at 510 nm using a spectrophotometer (Spec-tronic 200). The total flavonoid content was expressed as mg catechin equivalents (CE)/g DW of coffee. Each extract was analyzed in triplicate.

Determination of antioxidant capacities

Two different assays were performed to measure the antioxidant capacities of the coffee extracts, using ABTS and DPPH radicals, as previously described (Lim et al., 2012). The antioxidant capacity was expressed as mg vitamin C equivalents (VCE)/g DW of coffee. Each extract was analyzed in triplicate.

Calculation of the daily coffee consumption in the Korean diet

The amount of coffee consumed in the Korean diet was calculated based on the 24-hr dietary recall dataset of the Korea National Health and Nutrition Examination Survey in 2012 (KNHANES 2012), conducted by the Korea Centers for Disease Control and Prevention. The daily intakes of coffee per drinker were calculated as the total intakes of all the types of coffee used in the current study divided by the total number of coffee consumers. The KNHANES 2012 included 7213 participants who were randomly selected from all regions of the country. The 24-hr dietary recall was used to obtain information regarding the participant's diet consumed one day before this survey. The KNHANES 2012 was approved by the institutional review board of the Korea Centers for Disease Control and Prevention (IRB No. 2012-01EXP-01-2C).

Estimation of daily intakes of total phenolics, total flavonoids, and antioxidants

The daily intakes of total phenolics, total flavonoids, and antioxidants were assessed by the method of Chun et al. (2005).

The daily intake of total phenolics from various types of coffee products in the Korean diet was estimated from the level of total phenolics in coffee, as follows:

Daily intake of total phenolics per coffee drinker

(mg GAE/drinker/day)

$$= \sum (C_a P_{ia} + C_b P_{ib} + C_c P_{ic} + C_d P_{id}) / n_t$$

where C_a is the daily consumption of instant coffee, C_b is the daily consumption of decaffeinated instant coffee, C_c is the daily consumption of roasted coffee, C_d is the daily consumption of coffee mix, P_{ia} is the level of total phenolics in instant coffee, P_{ib} is the level of total phenolics in

decaffeinated instant coffee, P_{ic} is the level of total phenolics in roasted coffee, P_{id} is the level of total phenolics in coffee mix, and n_t is the total number of drinkers consuming instant coffee, decaffeinated instant coffee, roasted coffee, or coffee mix.

The daily intake of total flavonoids from various types of coffee products in the Korean diet was estimated from the level of total flavonoids in coffee, as follows:

Daily intake of total flavonoids per coffee drinker

(mg CE/drinker/day)

$$= \sum (C_a F_{ia} + C_b F_{ib} + C_c F_{ic} + C_d F_{id}) / n_t$$

where C_a is the daily consumption of instant coffee, C_b is the daily consumption of decaffeinated instant coffee, C_c is the daily consumption of roasted coffee, C_d is the daily consumption of coffee mix, F_{ia} is the level of total flavonoids in instant coffee, F_{ib} is the level of total flavonoids in decaffeinated instant coffee, F_{ic} is the level of total flavonoids in roasted coffee, F_{id} is the level of total flavonoids in coffee mix, and n_t is the total number of drinkers consuming instant coffee, decaffeinated instant coffee, roasted coffee, or coffee mix.

The daily intake of antioxidants from various types of coffee products in the Korean diet was calculated from the antioxidant capacity of coffee, as follows:

Daily intake of antioxidants per coffee drinker

(mg VCE/drinker/day)

$$= \sum (C_a V_{ia} + C_b V_{ib} + C_c V_{ic} + C_d V_{id}) / n_t$$

where C_a is the daily consumption of instant coffee, C_b is the daily consumption of decaffeinated instant coffee, C_c is the daily consumption of roasted coffee, C_d is the daily consumption of coffee mix, V_{ia} is the antioxidant capacity of instant coffee, V_{ib} is the antioxidant capacity of decaffeinated instant coffee, V_{ic} is the antioxidant capacity of roasted coffee, V_{id} is the antioxidant capacity of coffee mix, and n_t is the total number of drinkers consuming instant coffee, decaffeinated instant coffee, roasted coffee, or coffee mix.

Statistical analysis

All experiments were performed in triplicate. Tests for statistical significance were performed with IBM SPSS software Version 21 (IBM SPSS Statistics Inc., Chicago, IL, USA). The significance of differences ($p < 0.05$) was determined by Duncan's multiple range test.

Results and discussion

Total phenolics, total flavonoids, and antioxidant capacities

The total phenolic contents, total flavonoid contents, and antioxidant capacities of 21 brands of coffee products are presented in Table 1. The levels of total phenolics and total flavonoids ranged from 26.1 to 129.8 mg GAE/g and from 14.1 to 104.4 mg CE/g, respectively. The antioxidant capacities measured with the DPPH and ABTS assays varied widely, from 19.0 to 184.0 mg VCE/g and from 25.1

to 217.1 mg VCE/g, respectively. Among the coffee products tested, instant coffee had the highest average total phenolic content (117.2 mg GAE/g DW) and antioxidant capacities (135.5 mg VCE/g DW in the DPPH assay and 178.7 mg VCE/g DW in the ABTS assay), while coffee mix had the highest average total flavonoid content (69.3 mg CE/g DW). Roasted coffee had a lower average total phenolic content (26.2 mg GAE/g DW), total flavonoid content (14.6 mg CE/g DW), and antioxidant capacity (19.3 mg VCE/g DW for the DPPH assay and 25.6 mg VCE/g DW for the ABTS assay) than the other coffee products studied. The total phenolic contents and

Table 1 Total phenolic contents, total flavonoid contents, and antioxidant capacities of various coffee products commercially available in Korea

Types	Total phenolics (mg GAE/g DW)	Total flavonoids (mg CE/g DW)	Antioxidant capacities (mg VCE/g DW)	
			DPPH	ABTS
<i>Instant coffee</i>				
Brand A	94.2 ± 9.4 ^{e,f,g,l}	61.1 ± 0.4 ^{e,f,g,h}	96.9 ± 15.7 ^{e,f,g}	134.5 ± 4.7 ⁱ
Brand B	110.0 ± 4.1 ^{c,d}	70.6 ± 2.3 ^{c,d}	109.5 ± 3.3 ^{d,e,f}	152.7 ± 4.5 ^{h,i}
Brand C	103.3 ± 8.4 ^{c,d,e}	66.3 ± 1.7 ^{c,d,e}	104.8 ± 10.7 ^{d,e,f,g}	148.1 ± 11.0 ^{h,i}
Brand D	102.9 ± 6.9 ^{c,d,e}	59.6 ± 2.8 ^{e,f,g,h}	108.6 ± 5.4 ^{d,e,f}	154.6 ± 13.0 ^{h,i}
Brand E	129.5 ± 6.9 ^a	81.1 ± 3.8 ^b	141.9 ± 7.7 ^{b,c}	200.4 ± 16.6 ^{a,b,c}
Brand F	122.0 ± 9.6 ^{a,b}	85.9 ± 5.0 ^b	138.1 ± 4.1 ^c	217.1 ± 24.5 ^a
Brand G	123.5 ± 9.0 ^{a,b}	62.1 ± 1.0 ^{e,f,g}	155.5 ± 7.9 ^b	182.9 ± 9.4 ^{b,c,d,e,f}
Brand H	128.2 ± 2.4 ^a	59.8 ± 0.6 ^{e,f,g,h}	159.2 ± 8.8 ^b	189.6 ± 15.9 ^{b,c,d}
Brand I	129.8 ± 0.2 ^a	60.5 ± 2.5 ^{e,f,g,h}	184.0 ± 32.0 ^a	203.4 ± 8.8 ^{a,b}
Brand J	128.2 ± 2.7 ^a	57.4 ± 1.8 ^{g,h}	156.4 ± 9.6 ^b	204.0 ± 2.8 ^{a,b}
<i>Decaffeinated instant coffee</i>				
Brand K	110.4 ± 5.7 ^{c,d}	72.6 ± 2.6 ^c	118.0 ± 8.2 ^d	185.8 ± 5.2 ^{b,c,d,e}
Brand L	101.6 ± 11.7 ^{d,e}	65.3 ± 2.6 ^{d,e,f}	113.6 ± 8.9 ^{d,e}	170.4 ± 16.0 ^{d,e,f,g,h}
<i>Roasted coffee²</i>				
Brand M	26.3 ± 0.5 ^h	14.1 ± 0.3 ⁱ	19.6 ± 1.4 ^h	26.1 ± 0.2 ^j
Brand N	26.1 ± 0.1 ^h	15.1 ± 0.4 ⁱ	19.0 ± 1.1 ^h	25.1 ± 0.4 ^j
<i>Coffee mix</i>				
Brand O	85.5 ± 3.6 ^g	54.6 ± 4.8 ^h	91.5 ± 5.3 ^{f,g}	164.8 ± 19.9 ^{e,f,g,h}
Brand P	93.9 ± 5.6 ^{e,f,g}	55.4 ± 4.3 ^{g,h}	89.4 ± 5.6 ^g	159.7 ± 8.2 ^{g,h}
Brand Q	99.1 ± 3.5 ^{d,e,f}	59.8 ± 1.3 ^{e,f,g,h}	100.7 ± 4.1 ^{d,e,f,g}	165.5 ± 7.6 ^{e,f,g,h}
Brand R	86.7 ± 5.5 ^g	59.4 ± 9.6 ^{f,g,h}	93.8 ± 9.2 ^{f,g}	151.8 ± 15.7 ^{h,i}
Brand S	113.6 ± 8.9 ^{b,c}	81.2 ± 4.1 ^b	113.7 ± 7.3 ^{d,e}	179.2 ± 8.9 ^{c,d,e,f,g}
Brand T	101.6 ± 7.9 ^{d,e}	70.1 ± 5.7 ^{c,d}	109.3 ± 6.6 ^{d,e,f}	180.8 ± 7.2 ^{c,d,e,f,g}
Brand U	88.4 ± 4.4 ^{f,g}	104.4 ± 4.9 ^a	102.0 ± 6.6 ^{d,e,f,g}	162.8 ± 6.0 ^{f,g,h}
<i>Mean</i>				
Instant coffee	117.2 ± 13.3	66.4 ± 9.8	135.5 ± 29.1	178.7 ± 28.8
Decaffeinated instant coffee	106.0 ± 6.2	68.9 ± 5.2	115.8 ± 3.1	178.1 ± 10.9
Roasted coffee	26.2 ± 0.2	14.6 ± 0.7	19.3 ± 0.5	25.6 ± 0.7
Coffee mix	95.5 ± 10.1	69.3 ± 18.1	100.1 ± 9.2	166.4 ± 10.3

¹Data are presented as the mean ± standard deviation (n = 3). Different superscript letters in the same column for each type of coffee product indicate the significant differences by Duncan's multiple range test ($p < 0.05$)

²Data modified from Lim et al. (2012)

antioxidant capacities ranked in descending order as follows: instant coffee > decaffeinated instant coffee > coffee mix > roasted coffee. The average total flavonoid contents of the coffee products ranked in descending order as follows: coffee mix > decaffeinated instant coffee > instant coffee > roasted coffee. A wide ranges of total phenolic and flavonoid contents, and antioxidant capacities of coffee products used in this study may be due in part to the different roasting processes, origins, and cultivars of coffee (Kurniawan et al., 2017).

The total phenolic contents, total flavonoid contents, and antioxidant capacities of instant (soluble) coffee (instant coffee, decaffeinated instant coffee, and coffee mix) were greater than those of roasted coffee (Table 1). Similar to these results, it has been reported that the total phenolic content and antioxidant capacity of instant coffee were higher than those of roasted coffee, partly due to the fact that antioxidant components like the phenolic acids of roasted beans are extracted and concentrated during the manufacturing of instant coffee (Pérez-Hernández et al., 2012). The total phenolic contents of the four types of coffee products, with averages ranging from 26.2 to 117.2 mg GAE/g DW were lower than those of Arabica soluble coffee marketed in Brazil (Vignoli et al., 2011). In contrast, it was reported that instant coffee and roasted coffee had higher total phenolic contents than those determined in this study (Lakenbrink et al., 2000).

Daily consumption of coffee per drinker in the Korean diet

Among the 7213 participants in the KNHANES 2012, the total number of coffee consumers was 3562, approximately 49.4% of the total population (Fig. 1). The numbers of drinkers of the four types of coffee products in the KNHANES 2012 are shown in Fig. 1. The numbers of

drinkers of instant coffee, decaffeinated instant coffee, roasted coffee, and coffee mix were 1372, 10, 483, and 2134, respectively. No one drank all four types of coffee in the KNHANES 2012. Coffee consumers who drank at least two types of coffee in a single day comprised approximately 11.8% of the total coffee consumers or 422 persons. Among consumers drinking two or more types of coffee products, 279 people consumed both instant coffee and coffee mix in a day, and 15 consumers drank three types of coffee products (instant coffee, coffee mix, and roasted coffee) per day.

Daily intakes of coffee were derived from the large dataset of the KNHANES 2012, in which a 24-hr dietary recall was conducted to gain information on each respondent’s food intake one day before the survey. The daily coffee consumption per drinker (g/drinker/day) ranked in descending order as follows: roasted coffee > instant coffee > coffee mix > decaffeinated instant coffee, which corresponded to 11.23, 3.82, 3.12, and 1.53 g, respectively, according to the survey dataset of the KNHANES 2012 (data not shown).

Figure 2A compares the percentages (%) of consumers drinking the four types of coffee products tested in this study among the gender and age groups of the KNHANES 2012 respondents. Men comprised 41.9% and women comprised 58.1% of total coffee drinkers (Fig. 2A), which means that the number of coffee drinkers was higher in women than men. The percentages of total daily coffee consumption by age and gender subgroups are shown in Fig. 2B. Male and female consumers contributed to 51.1 and 48.9%, respectively, of the total daily coffee intake in the KNHANES 2012. Men had higher intakes of instant coffee and coffee mix than women, while women had a higher intake of roasted coffee than men. Persons in their forties consumed more coffee than those in other age groups.

Generally, commercial coffee mixes and roasted coffee products in Korea are prepared with approximately 12 g of stick per 100-mL cup and 8 g per 240-mL cup, respectively. A 12-g stick of coffee mix contains about 1.8 g of soluble coffee. Instant coffee and decaffeinated instant coffee are prepared with 2 g/100 mL. Although the daily coffee consumption per drinker (g/drinker/day) ranked in descending order as roasted coffee > instant coffee > coffee mix > decaffeinated instant coffee, the consumption on the basis of cups ranked in the following descending order: instant coffee (1.91 cups) > coffee mix (1.73 cups) > roasted coffee (1.40 cups) > decaffeinated instant coffee (0.77 cups) (data not shown). This suggests that instant coffee is a more preferable choice to drink than roasted coffee. The daily consumption of the three types of soluble coffee (instant coffee, coffee mix, and decaffeinated instant coffee) was estimated to be

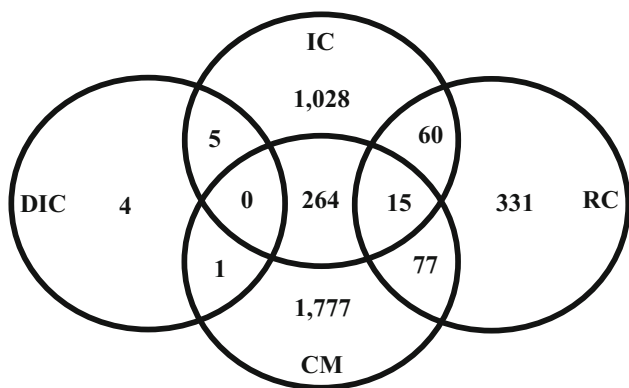
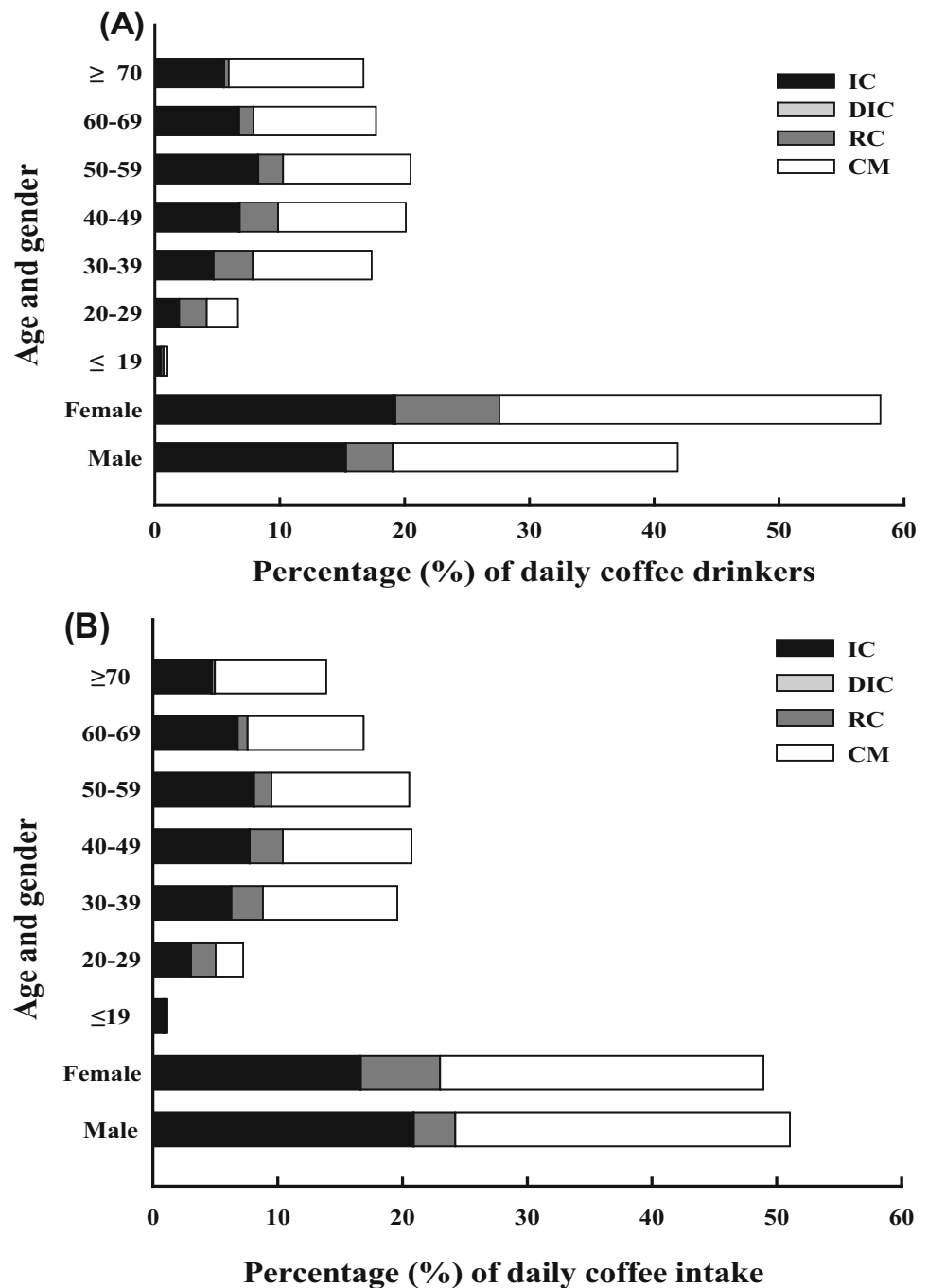


Fig. 1 The numbers of drinkers of four types of coffee products from a total of 7213 participants in the Korea National Health and Nutrition Examination Survey in 2012. *IC* instant coffee, *DIC* decaffeinated instant coffee, *RC* roasted coffee, *CM* coffee mix

Fig. 2 Percentage of the number of daily coffee drinkers (A) and daily coffee intake (g/drinker/day) based on serving size (B) of instant coffee (IC), decaffeinated instant coffee (DIC), roasted coffee (RC), and coffee mix (CM) with respect to age and gender in the Korea National Health and Nutrition Examination Survey in 2012 (KNHANES 2012). The number of coffee drinkers was 3562 (about 49.4%) among the total of 7213 participants in the KNHANES 2012



3.46 g/drinker/day (data not shown). The number of soluble coffee consumers was 3231 (Fig. 1), who consumed approximately 6320 cups/day/drinker. Therefore, instant coffee drinkers in Korea consumed a daily average of 2.0 cups. A Polish cohort study demonstrated that 83% of the population drank at least 1 cup of coffee per day (Grosso et al., 2014), while about 49.4% of people consumed one of the four types of coffee daily in Korea in 2012 (Fig. 1). Coffee mix was the most preferred of the four coffee types (Fig. 1). Approximately 60% of coffee drinkers in the

KNHANES 2012 consumed coffee mix, followed by drinkers of instant coffee at about 38.5% of total coffee consumers.

More than 92% of the consumers were ≥ 30 years old in this survey (Fig. 2A). Regarding the age categories, over 58% of the coffee drinkers in the KNHANES 2012 were 30–59 years old (Fig. 2A). This might be attributable to the easy access to coffee at the workplaces for people in their thirties, forties, and fifties. The lower number of younger coffee drinkers such as teens and 20-year-olds may have

been due to their reluctant consumption of caffeinated coffee and being less accustomed to drinking coffee than those in older age groups. Although the number of female coffee drinkers was 16.2% greater than the number of male coffee drinkers (Fig. 2A), the discrepancy between men and women in the percentage of daily coffee intake was only about 2.2% (Fig. 2B), suggesting that men consumed greater amounts of coffee in a day or at a time than women. Similar to these results, it has been reported that mean intakes of coffee were higher in men than women among coffee drinkers in the United States (Loftfield et al., 2016).

Frequency of coffee consumption

The frequencies (times/drinker/day) of consumption of instant coffee, decaffeinated instant coffee, roasted coffee, and coffee mix from the KNHANES 2012 are presented in Table 2. The median frequency for each type of coffee was 1.00 time/drinker/day. Coffee mix was the most frequently consumed at 1.73 times/drinker/day, whereas roasted coffee was consumed with the least frequently at 1.39 times/drinker/day. The widest range of coffee consumption frequencies was found for coffee mix, at 1–30 times/drinker/day.

Daily intakes of total phenolics, total flavonoids, and antioxidants

Based on the KNHANES 2012, the daily per drinker intakes of total phenolics, total flavonoids, and antioxidants from commercially available coffee in the Korean diet are shown in Table 3. Coffee drinkers had daily intakes of total phenolics from 155.4 mg GAE/drinker/day (decaffeinated instant coffee brand L) to 496.4 mg GAE/drinker/day (instant coffee brand I). The daily intakes of total flavonoids per coffee drinker ranged from 99.8 mg CE/drinker/day (decaffeinated instant coffee brand L) to 328.5 mg CE/drinker/day (instant coffee brand F). For the DPPH assay, the daily intakes of antioxidants per coffee drinker ranged from 173.8 VCE/drinker/day (decaffeinated instant coffee brand L) to 703.8 VCE/drinker/day (instant coffee brand I). The daily per drinker antioxidant intakes as

measured by the ABTS assay varied widely from 260.7 VCE/drinker/day (decaffeinated instant coffee brand L) to 830.3 VCE/drinker/day (instant coffee brand F). The average daily intakes of total phenolics, total flavonoids, and antioxidants all decreased in the following order: instant coffee > coffee mix > roasted coffee > decaffeinated instant coffee (Table 3). The average daily intakes per coffee drinker of total phenolics and total flavonoids were 348.6 mg GAE and 222.5 mg CE, respectively. The average daily intakes of antioxidants per coffee drinker were 370.8 mg VCE in the DPPH assay and 546.7 mg VCE in the ABTS assay.

Coffee, one of major dietary contributors, was previously reported to account for approximately 40% of the total phenolic intake, which is equivalent to the total phenolic intake of about 696.3 mg/day from coffee (Grosso et al., 2014). The daily intake of total phenolics among coffee consumers in the KNHANES 2012 was 348.6 mg GAE/drinker (Table 3). The difference in the total phenolic intakes may have been due to the fact that only four types of coffee products were evaluated in our study, which did not include bottled coffee beverage products in various forms (cans or plastic bottles) and that, unlike the unit expression of this study, the total phenolic intake in the previous study was calculated as the sum of all the individual phenolics (Grosso et al., 2014).

Instant coffee products are known to possess antioxidant capacity due to antioxidant components such as phenolics, caffeine, and melanoidins (Vignoli et al., 2011; Yashin et al., 2013). Coffee is known to be one of the richest dietary sources of antioxidants such as chlorogenic acid for coffee drinkers. Therefore, coffee consumption may deliver a significant amount of antioxidants such as phenolics to the body. Coffee has been linked to an increasing number of potential health benefits, including an increased antioxidant capacity (Higdon and Frei, 2006; Yashin et al., 2013). Furthermore, studies have suggested that coffee might provide protection from liver cancer or chronic hepatitis (Clemens and Coughlin, 2007; Kalthoff et al., 2010). Coffee has stimulating effects on the central nervous system and blood circulation (George et al., 2008), but these effects may be negative for people who are sensitive

Table 2 Frequency of drinking instant coffee, decaffeinated instant coffee, roasted coffee, and coffee mix from the Korea National Health and Nutrition Examination Survey in 2012

Types	Coffee-drinking frequency (times/drinker/day)			
	Range ¹	Mean	Standard deviation	Median
Instant coffee	1–14	1.65	1.23	1.00
Decaffeinated instant coffee	1–4	1.70	1.06	1.00
Roasted coffee	1–5	1.39	0.76	1.00
Coffee mix	1–30	1.73	1.36	1.00

¹Units of instant coffee, decaffeinated instant coffee, roasted coffee, and coffee mix are a 100-mL cup, a 100-mL cup, a 240-mL cup (8 g of roasted beans), and a coffee stick (12 g), respectively

Table 3 Daily per drinker intakes of total phenolics, total flavonoids, and antioxidants from coffee products commercially available in Korea

Types	Total phenolics (mg GAE ¹ /drinker/day)	Total flavonoids (mg CE ² /drinker/day)	Antioxidants (mg VCE ³ /drinker/day)	
			DPPH ⁴	ABTS ⁵
<i>Instant coffee</i>				
Brand A	360.3	233.7	370.6	514.4
Brand B	420.7	270.0	418.9	584.0
Brand C	395.1	253.6	400.7	566.4
Brand D	393.5	227.9	415.4	591.3
Brand E	495.3	310.2	542.7	766.4
Brand F	466.6	328.5	528.0	830.3
Brand G	472.3	237.5	594.8	699.5
Brand H	490.3	228.7	608.8	725.1
Brand I	496.4	231.4	703.8	777.9
Brand J	490.3	219.5	598.3	780.2
<i>Decaffeinated instant coffee</i>				
Brand K	168.9	111.1	180.5	284.3
Brand L	155.4	99.8	173.8	260.7
<i>Roasted coffee</i>				
Brand M	295.4	158.2	220.1	293.4
Brand N	292.8	169.3	212.9	282.2
<i>Coffee mix</i>				
Brand O	266.4	170.3	285.3	513.9
Brand P	292.6	172.6	278.6	497.7
Brand Q	308.9	186.5	313.9	515.8
Brand R	270.3	185.2	292.3	473.3
Brand S	354.2	253.1	354.6	558.5
Brand T	316.6	218.5	340.6	563.5
Brand U	275.7	325.4	318.1	507.6
<i>Mean</i>				
Instant coffee	448.1	254.1	518.2	683.6
Decaffeinated instant coffee	162.2	105.4	177.1	272.5
Roasted coffee	294.1	163.7	216.5	287.8
Coffee mix	297.8	215.9	311.9	518.6
Total	348.6	222.5	370.8	546.7

¹GAE stands for gallic acid equivalents

²CE stands for catechin equivalents

³VCE stands for vitamin C equivalents

⁴Antioxidants measured using the DPPH radical scavenging assay

⁵Antioxidants measured using the ABTS radical scavenging assay

to stimulants or have anxiety disorders. Regular caffeine usage appears to be beneficial, with higher users having better mental function. The moderate daily consumption of 3–4 cups of coffee with an average caffeine concentration of 60–85 mg/cup has been suggested to be good for health (Smith, 2002). In the Spanish diet, coffee was found to be the main contributor to antioxidant intake; the daily intake per capita was 356 mg vitamin C equivalents in the ABTS assay (Pulido et al., 2003). In this study, the antioxidant intakes from coffee were estimated to be 546.7 mg

VCE/drinker/day in the ABTS assay, and 370.8 mg VCE/drinker/day in the DPPH assay (Table 3).

Distribution of daily intakes of total phenolics, total flavonoids, and antioxidants from coffee

The distributions of daily intakes of total phenolics, total flavonoids, and antioxidants from coffee are illustrated in Fig. 3. The distributions of daily total phenolic intake from the four types of coffee products are shown in Fig. 3A. For

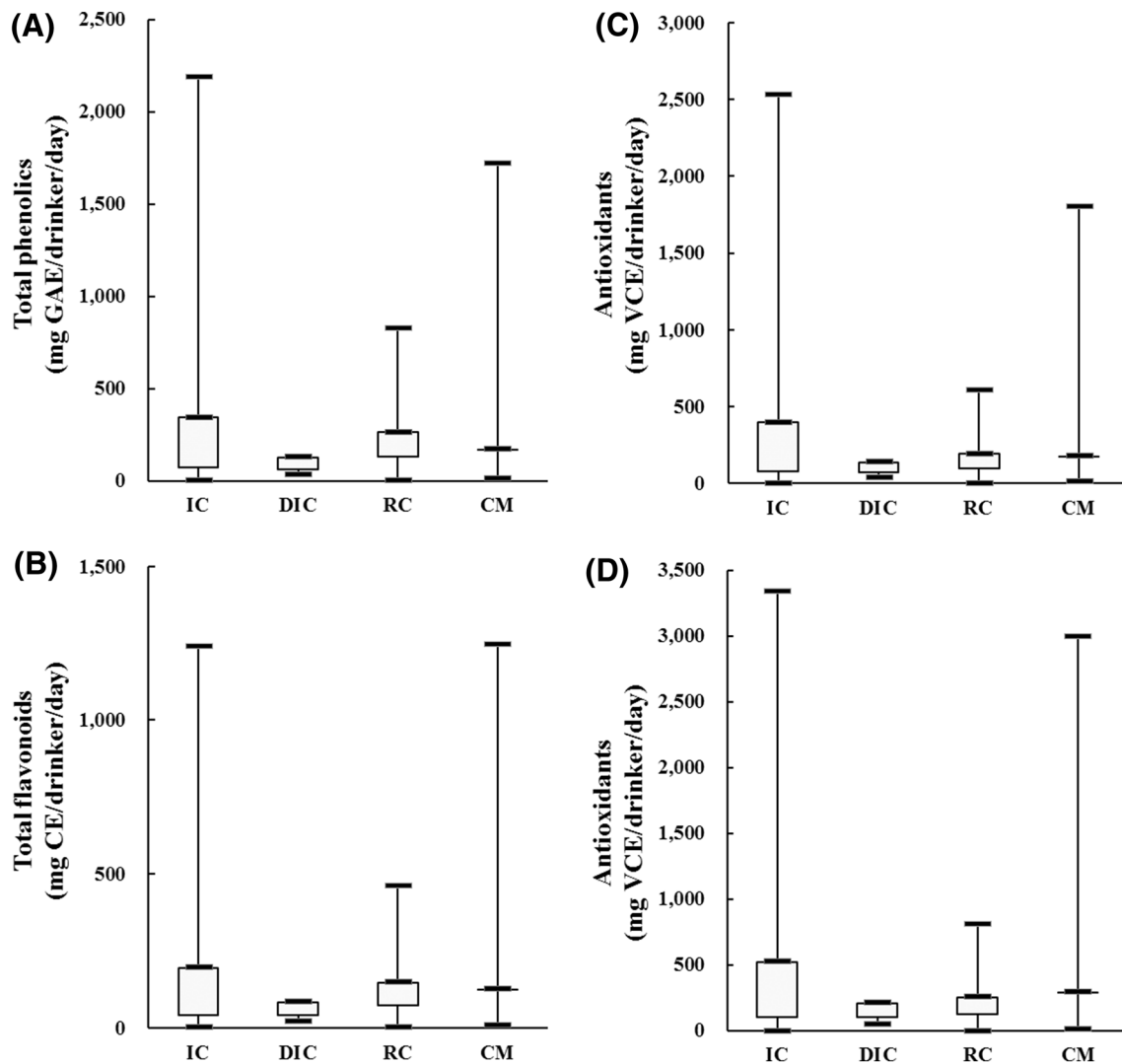


Fig. 3 Box-and-whisker plots showing the minimum and maximum (vertical line), median (center horizontal line), and first and third quartiles (box) of daily intake of total phenolics (A), total flavonoids (B), and antioxidants measured with the DPPH (C) and

(D) assays from four types of coffee products. *IC* instant coffee, *DIC* decaffeinated instant coffee, *RC* roasted coffee, *CM* coffee mix, *GAE* gallic acid equivalents, *CE* catechin equivalents, *VCE* vitamin C equivalents

instant coffee, the minimum and maximum daily intakes of total phenolics extended over an approximately 7290-fold range, between 0.3 and 2187.0 mg GAE/drinker/day, with a median value of 312.4 mg GAE/drinker/day. For decaffeinated instant coffee, the minimum and maximum daily intakes of total phenolics extended over an approximately fourfold range, between 31.8 and 127.2 mg GAE/drinker/day, and the median daily total phenolic intake of 127.2 mg GAE/drinker/day was basically the same as the 75th percentile of daily total phenolic intake. For roasted coffee, the minimum and maximum daily intakes of total phenolics extended over an approximately 2748-fold range, between 0.3 and 824.5 mg GAE/drinker/day, with a median value of 183.2 mg GAE/drinker/day. For coffee mix, the minimum and maximum daily intakes of total phenolics

extended over an approximately 200-fold range, between 8.6 and 1719.7 mg GAE/drinker/day. The median, 25th percentile, and 75th percentile values of daily total phenolic intake from coffee mix were all equal to 172.0 mg GAE/drinker/day.

The distributions of daily total flavonoid intakes from the four types of coffee products are shown in Fig. 3B. For instant coffee, the minimum and maximum daily total flavonoid intakes extended over an approximately 12,402-fold range, between 0.1 and 1240.2 mg CE/drinker/day, and the median daily intake of total flavonoids was 177.2 mg CE/drinker/day. For decaffeinated instant coffee, the minimum and maximum daily intakes of total flavonoids extended over an approximately fourfold range, between 20.7 and 82.7 mg CE/drinker/day, and the median

daily total flavonoid intake of 82.7 mg CE/drinker/day was basically the same as the 75th percentile of daily total flavonoid intake. For roasted coffee, the minimum and maximum daily intakes of total flavonoids extended over an approximately 4591-fold range, between 0.1 and 459.1 mg CE/drinker/day, and the median daily intake of total flavonoids was 102.0 mg CE/drinker/day. For coffee mix, the minimum and maximum daily intakes of total flavonoids extended over an approximately 201-fold range, between 6.2 and 1246.9 mg CE/drinker/day. The median, 25th percentile, and 75th percentile values of daily total flavonoid intake from coffee mix were all equal to 124.7 mg CE/drinker/day.

For the four types of coffee products, the distributions of daily intakes of antioxidants measured in the DPPH assay are shown in Fig. 3C. For instant coffee, the minimum and maximum daily intakes of antioxidants extended over an approximately 8430-fold range, between 0.3 and 2529.2 mg VCE/drinker/day, and the median daily intake of antioxidants was 361.3 mg VCE/drinker/day. For decaffeinated instant coffee, the minimum and maximum daily intakes of antioxidants extended over an approximately fourfold range, between 34.7 and 138.9 mg VCE/drinker/day, and the median daily antioxidant intake of 138.9 mg VCE/drinker/day was basically the same as the 75th percentile of daily antioxidant intake. For roasted coffee, the minimum and maximum daily intakes of antioxidants extended over an approximately 3035-fold range, between 0.2 and 607.0 mg VCE/drinker/day, and the median daily intake of antioxidants was 134.9 mg VCE/drinker/day. For coffee mix, the minimum and maximum daily intakes of antioxidants extended over approximately 200-fold range, between 9.0 and 1801.0 mg VCE/drinker/day. The median, 25th percentile, and 75th percentile values of daily antioxidant intake from coffee mix were all equal to 180.1 mg VCE/drinker/day.

For the four types of coffee products, the distributions of daily intakes of antioxidants measured in the ABTS assay are shown in Fig. 3D. For instant coffee, the minimum and maximum daily intakes of antioxidants extended over an approximately 8341-fold range, between 0.4 and 3336.3 mg VCE/drinker/day, and the median daily intake of antioxidants was 476.6 mg VCE/drinker/day. For decaffeinated instant coffee, the minimum and maximum of daily intakes of antioxidants extended over an approximately fourfold range, between 53.4 and 213.7 mg VCE/drinker/day, and the median daily antioxidant intake of 213.7 mg VCE/drinker/day was basically the same as the 75th percentile of daily antioxidant intake. For roasted coffee, the minimum and maximum daily intakes of antioxidant extended over an approximately 2690-fold range, between 0.3 and 807.0 mg VCE/drinker/day, and the median daily intake of antioxidants was 179.3 mg

VCE/drinker/day. For coffee mix, the minimum and maximum daily intakes of antioxidants extended over an approximately 200-fold range, between 15.0 and 2994.7 mg VCE/drinker/day. The median, 25th percentile, and 75th percentile values of daily antioxidant intake from coffee mix were all equal to 299.5 mg VCE/drinker/day.

The KNHANES 2012 analysis revealed that the coffee-drinking frequencies (times/drinker/day) for the four types of coffee products were widely distributed, varying by as much as 1–30 times per day for coffee mix (Table 2). The mean frequency increased as follows: roasted coffee (1.39) < instant coffee (1.65) < decaffeinated instant coffee (1.70) < coffee mix (1.73). Although the mean coffee-drinking frequencies did not differ much (Table 2), the box-and-whisker plots revealed very wide gaps in the daily per drinker intakes of total phenolics, total flavonoids, and antioxidants (Fig. 3). For instant coffee, about a 7290-fold difference existed between the minimum and maximum daily intakes of total phenolics, while there was an approximately 2748-fold intake difference for roasted coffee (Fig. 3A). The same trends were observed for total flavonoids and antioxidants (Fig. 3B–D). The huge gaps in daily intakes from coffee consumption might reflect various factors, such as consumers' preferences and the accessibility of coffee products.

In Korea, about half of those who participated in the KNHANES 2012 drank one of the four types of coffee products in this study. Most coffee drinkers consumed approximately 2.0 cups of instant coffee or 1.4 cups of roasted coffee every day, where a cup was assumed to be 2 g in 100 mL of water for instant coffee and decaffeinated instant coffee, 8 g in 240 mL of water for roasted coffee, and 12 g in 100 mL of water for coffee mix. In environments where there is easy access to coffee products every day, the consumption of various coffee products and the age and sex categories of the consumers may influence the daily intakes of total phenolics, total flavonoids, and antioxidants. In the current study, the estimated dietary intakes of total phenolics, total flavonoids, and antioxidants in the Korean diet were somewhat limited due to the exclusion of various canned and bottled coffee products that are commercially available in the Korean market. Nevertheless, it is believed that this study is the first step toward generating baseline data on the daily per capita intakes of total phenolics, total flavonoids, and antioxidants from coffee in the Korean diet.

In conclusion, in this study, the daily per drinker intakes (mg/drinker/day) of total phenolics, total flavonoids, and antioxidants from coffee in the Korean diet were estimated with a combination of experimental measurements and dataset analysis of the KNHANES 2012. In terms of age categories, people 30–59 years old accounted for over 58% of the coffee drinkers in the KNHANES 2012. The daily

per drinker intakes were estimated to be 348.6 mg GAE for phenolics, 222.5 mg CE for flavonoids, and 370.8 mg VCE (DPPH assay) or 546.7 mg VCE (ABTS assay) for antioxidants. This study revealed that coffee drinker in Korea drank around 1.4 cups of roasted coffee or 2.0 cups of instant coffee every day. In further studies, the contribution of coffee compared to various foods such as fruits, vegetables, and tea in the Korean diet, and the daily consumption of chlorogenic acid as a major phenolic in coffee, will need to be estimated.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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