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Comparative Studies on Chemical Composition, Phenolic Compounds and Antioxidant Activities of Brown and White Perilla (*Perilla frutescens*) Seeds

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ABSTRACT

Chemical composition, phenolic compounds and antioxidant activities of brown perilla and white perilla seeds were comparatively studied. Brown perilla seed had higher protein, fat, ash and crude fiber contents than those of white perilla seed ($p < 0.05$). Additionally, brown perilla seed contained greater contents of Ca, Mg, and P than those of white perilla seed ($p < 0.05$). However, no difference in Fe content was found in both seeds ($p > 0.05$). Brown perilla seed was rich in polyunsaturated fatty acid, in particular γ -linolenic acid and α -linolenic acid. The most abundant of β -carotene and α -tocopherol was found in brown perilla seed. Higher total phenolic, total flavonoid, and total flavonol contents together with higher 2, 2-diphenyl-1-picrylhydrazyl (DPPH) and 2, 2'-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid) (ABTS)-radical scavenging activities as well as a greater reducing capacity were observed in brown perilla seed extract ($p < 0.05$). Therefore, brown perilla seed can be a good source of both macro- and micro-nutrients with phytochemical antioxidant activity.

Keywords: perilla seed, chemical composition, phenolic compound, antioxidant activity

1. INTRODUCTION

Perilla seed (*Perilla frutescens*), also known as “Nga-Kee-Mon” is an oil seed grown in Northern of Thailand, particularly in Prachinburi, Nan, Meahongson, and Chiang Mai provinces.

This seed was also reported as a food plant commonly used in Asia cuisine, especially in Korea (kaennip) and Japan (shiso) [1]. In Thailand, perilla seed is generally used as an ingredient for traditional snack foods such as

“nga-tum-aoi” (ground perilla seed mixed with cane sugar paste), “khaow-nuk-nga” (cooked glutinous rice mixed with roasted perilla seed), and “nga-ud-tang” (sweetened perilla seed bar). Perilla seed has been paid more attention on nutritional improvements for bakery and Thai dessert products because perilla seed is a good source of protein (17%) and fat (51%) [2]. Major fatty

acids of perilla oil are unsaturated fatty acids such as oleic acid (14-23%), linoleic acid (11-16%) and linolenic acid (54-64%) [3]. Gunstone *et al.* [4] and Kanchanamayoon and Kanenil [5] reported that perilla seed was a rich source of α -linolenic acid (ALA, C18:3, n3), accounting for approximately 60% of total fatty acids. Siriamornpun *et al.* [6] also reported the high ratio of polyunsaturated fatty acid to saturated fatty acid in perilla seed. In addition, perilla seed is an excellent source of phenolic compounds such as phenolic acids, flavonoids, and triterpenoids which has been known to exhibit several health beneficial activities including antioxidant, antibiotic, and antipyretic properties [7,8]. Phenolic compounds, generally known as secondary metabolites, are widely distributed in both leaves and seed. Lee *et al.* [9] found four phenolic acids and five flavonoids in Korean perilla seed.

In Thailand, especially in Maehongson, two varieties of perilla are cultivated, namely brown and white perilla seeds. Brown perilla seed is generally used in cooking and traditional medicine. Due to the lower cultivation of white perilla seed, it is only used for traditional food. Additionally, high amount of total lipid and unsaturated fatty acids, especially n3 fatty acid, in both Thai perilla seeds had been reported [10]. However, no basic information regarding the nutritional composition, phenolic compounds and antioxidant activities of those perilla seeds harvested in Maehongson, Thailand has been reported. Therefore, the objective of this investigation was to compare the chemical compositions, phenolic compounds and antioxidant activities of brown perilla and white perilla seeds cultivated in Maehongson, Thailand.

2. MATERIALS AND METHODS

2.1 Chemicals

β -carotene type I, quercetin, 2, 2'-diphenyl-1-picrylhydrazyl (DPPH), 2, 2'-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS), ($\pm$)-6-hydroxy-2,5,7,8-tetramethyl-chromane-2-carboxylic acid (Trolox), 2,4,6-tris (2-pyridyl)-S-triazine (TPTZ), Folin-Ciocalteu reagent and heptadecanoic acid were purchased from Sigma-Aldrich (St. Louis, Mo, USA). Fatty acid methyl ester standard (C4-C24) was purchased from Supelco (PA, USA). Gallic acid was purchased from Fluka (Buchs, Switzerland).

2.2 Perilla Seed Sample Collection

Brown and white perilla seeds were obtained from Maehongson, Thailand. Both seeds were harvested during December 2013. Samples were vacuum packed in aluminum bag (100g/bag) and transferred to Food and Nutrition Laboratory, Kasetsart University within 18 h. The samples were stored at -80°C until used.

2.3 Proximate Analysis

Perilla seed sample was ground in a grinder (AT710131, Moulinex, France) for 1 min. Ground samples (20-mesh) were analyzed for moisture, protein, fat, ash, crude fiber and total carbohydrate contents by the methods of AOAC [11].

2.4 Determination of Minerals

Mineral analysis including calcium (Ca), magnesium (Mg), iron (Fe), phosphorus (P), zinc (Zn) and potassium (K), were determined by inductively coupled plasma emission spectrometer (Optima 3300 DV, Perkin-Elmer, United States) according to the AOAC method [11].

2.5 Determination of β -carotene

β -carotene content of brown and white perilla seeds was determined according to the method of Kurilich and Juvik [12] with a slight modification. The β -carotene, calculated from the standard curve of β -carotene (type I) was expressed as mg β -carotene/g dry weight.

2.6 Determination of α -tocopherol Content

The content of α -tocopherol in brown and white perilla seeds was quantified by using a high performance liquid chromatography (HPLC) (1200 LC System) with a diode-array detector (DAD) (Agilent Technologies, CA, USA). Sample was prepared as described by Qian and Sheng [13].

2.7 Determination of Lipid Composition and Fatty Acid Profile

Brown and white perilla seed lipids were extracted by the method of Bligh and Dyer [14]. The lipid composition was determined by thin-layer chromatography/flame ionization detector (TLC-FID). The identified chromatographic peak area was quantified and expressed as % of total lipid.

The fatty acid compositions of lipids from brown and white perilla seeds were determined as fatty acid methyl ester (FAME) using gas chromatography 6890N (Agilent Technologies, CA, USA). The FAME was prepared according to the method of AOAC [11]. Separation was accomplished on a BPX70 capillary column (50 m length $\times$ 0.25 mm inner diameter $\times$ 0.25 μ m film thickness from SGE, Australia). Retention time of FAME standards was used to identify chromatographic peaks. Peak area was quantified and expressed as % of total lipid [11].

2.8 Determination of Some Bioactive Compounds and Antioxidant Activity

2.8.1 Preparation of crude extracts of perilla seeds

Brown and white perilla seeds were extracted with 80% ethanol according to the method of Peng *et al.* [15]. Sample was dried at 60°C for 2 h and ground into powder (20-mesh) with a blender (AT710131, Moulinex, France). The ground sample was extracted with 10 ml of 80% ethanol in an ultrasonic bath (Transsonic TP 690, Elma, Singen, Germany) at room temperature (25°C) for 2 h. The mixture was filtered through with a 0.22 mm nylon filter and adjusted to 10 ml with 80% ethanol. The extract was kept in amber glass bottle and stored at 4°C until analysis for bioactive compounds and antioxidant activity.

2.8.2 Determination of some bioactive compounds

2.8.2.1 Total phenolic content

Total phenolic content of extracts from brown and white perilla seeds was determined by Folin-Ciocalteu micro-method [16]. Total phenolic content was calculated from the standard curve of gallic acid and expressed as μ g gallic acid equivalent (GAE)/g dry weight of sample.

2.8.2.2 Total flavonoid content

Total flavonoid content of extracts from brown and white perilla seeds was determined as described by Ordoñez *et al.* [17]. Total flavonoid content of extract was calculated from the standard curve of quercetin and expressed as μ g quercetin equivalent (QE)/g dry weight of sample.

2.8.2.3 Total flavonol content

Total flavonol content of extracts from brown and white perilla seeds was determined

according to the method of Kumaran and Joel [18]. The total flavonol content was calculated from the standard quercetin and expressed as $\mu\text{g QE/g}$ dry weight of sample.

2.8.3 Determination of antioxidant activity

2.8.3.1 DPPH radical scavenging activity

DPPH radical scavenging activity of brown and white perilla seed extracts was measured as described by Yen and Hsieh [19]. The extract (40 μl) was added with 2 ml of DPPH solution (0.12 mM in 95% methanol). The mixture was mixed well and incubated at room temperature for 30 min. The absorbance at 517 nm of the mixture was measured using a spectrophotometer. The control was prepared in the same manner but 80% ethanol was used instead of perilla seed extract. All operations were done in dark condition. The percentage of DPPH scavenging activity was calculated.

2.8.3.2 ABTS cation radical scavenging activity

ABTS cation radical scavenging activity was determined by Re *et al.* [20]. The ABTS cation radical scavenging activity was calculated and expressed as $\mu\text{mol Trolox equivalent (TE)}/\text{g}$ dry weight sample.

2.8.3.3 Ferric reducing antioxidant power (FRAP)

FRAP of perilla seed extracts was measured by the method of Benzie and Strain [21]. The FRAP was calculated and expressed as $\mu\text{mol TE/g}$ dry weight sample.

2.8.3.4 Reducing power

Reducing power of extracts was carried out according to Oyaizu [22]. The reducing power of sample was calculated and expressed as BHT equivalents/100 g dry

weight sample.

2.9 Statistical Analysis

Data were subjected to analysis of variance (ANOVA). Comparison of mean was carried out by independent t-test [23].

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Brown Perilla and White Perilla Seeds

Differences in compositions of brown perilla and white perilla seeds were observed ($p < 0.05$) (Table 1). Generally, brown perilla seed had lower moisture content than white perilla seed ($p < 0.05$). The moisture content could be used as an indicator for predicting the storage time. Saklani *et al.* [24] reported that perilla seed from India contained 8% moisture content. According to the information from farmers, they usually dry perilla seeds after harvesting by sun-drying for 2-3 days. The lowering moisture content was desirable for shelf-life extension because higher moisture content can enhance the microbial and enzymatic activities, leading to deterioration or the loss in nutritional value of the oil seed [25].

Higher protein content in brown perilla seed was found ($p < 0.05$) (Table 1). In general, perilla seed protein is located in seed kernel [26], which contained 15.7-23.9% protein content [26,27]. In addition, Longvah and Deosthale [26] reported that the essential amino acids of perilla seed represented 39% of total amino acid content but limiting in lysine could be observed.

Obviously, brown perilla seed had higher fat content than that found in white perilla seed for 5.6 times (Table 1) ($p < 0.05$). In general, perilla seed is a source of edible oil, however, the total lipid content in brown and white perilla seeds was only 20.27% and 3.59%, respectively. The difference fat content depends on many factors such as the

maturation period, harvesting time, ripening stage of the seed, environmental conditions, cultivation climate, season and location [6]. The results showed brown perilla seed can be used as a source of edible oil.

Ash content of brown perilla and white perilla seeds were 3.37% and 3.34%, respectively (Table 1). The ash content is an indication of the mineral content of the perilla seed. From the results, ash content in both perilla seeds was lower than sesame and basil seeds [28,29]. Generally, brown perilla seed had higher content of crude fiber than had white perilla seed ($p < 0.05$) (Table 1). Several researches reported that crude fiber

of perilla seed was 20.68-23.27%, which was higher than that of sesame (3-6%) [30,31]. The amount of total carbohydrate in perilla seed was 33.96% for brown perilla seed and 56.88% for white perilla seed, respectively (Table 1). In general, oilseed carbohydrate, such as sesame seed, contained sugars and most of which are reducing type [32]. Thus, the difference in carbohydrate content of both perilla seeds was probably due to the difference in sugar content. From the results, perilla seeds, especially brown seed, is a good dietary source for food production, which can be utilized for human or animal consumption.

Table 1. Proximate composition of brown perilla and white perilla seeds.

Composition	Brown perilla seed	White perilla seed
Moisture (%)	4.82±0.02 ^b	6.82±0.10 ^a
Protein (% dry weight)	19.13±0.19 ^a	15.51±0.09 ^b
Fat (% dry weight)	20.27±0.31 ^a	3.59±0.07 ^b
Ash (% dry weight)	3.37±0.02 ^a	3.34±0.02 ^b
Crude fiber (% dry weight)	23.27±0.05 ^a	20.68±0.18 ^b
Total carbohydrate (% dry weight)	33.96±0.40 ^b	56.88±0.12 ^a

Means ± SD from triplicate determinations with different superscript letters in the same row indicate significant differences ($p < 0.05$).

3.2 Mineral Content

The contents of different minerals in both perilla seeds, brown and white seeds, are presented in Table 2. Brown perilla seed had higher content of Ca, Mg and P than had white perilla seed ($p < 0.05$). No difference in Fe content was observed ($p > 0.05$). Both perilla seeds contained slightly different Zn content. White perilla seed exhibited greater K content than brown perilla seed ($p < 0.05$). From the results, it was found that Ca and P were the dominant minerals in both perilla seeds. Iron is a transition metal ion which has been known as the major catalyst for oxidation. Thus, Fe might contribute to the oxidation of perilla seed lipid during processing and subsequent storage.

3.3 β -carotene and α -tocopherol Contents

The content of β -carotene in brown perilla and white perilla seeds are shown in Table 3. Generally, β -carotene content in brown perilla seed was 0.62 mg/g dry weight. However, the content of β -carotene in white perilla seed was not detectable. Generally, β -carotene is a provitamin A, which is an essential nutrient required for maintaining immune function, eye health, vision, growth and survival in human being [33]. In addition, carotenoid is acting as a primary antioxidant by trapping free radicals or as a secondary antioxidant by quenching singlet oxygen.

Table 2. Mineral contents (mg/g dry weight) in brown perilla and white perilla seeds.

Composition	Brown perilla seed	White perilla seed
Ca	5.13±0.05 ^a	4.00±0.04 ^b
Mg	2.76±0.00 ^a	2.35±0.03 ^b
Fe	0.12±0.00 ^a	0.12±0.00 ^a
P	6.54±0.05 ^a	5.14±0.12 ^b
Zn	0.03±0.00 ^b	0.04±0.00 ^a
K	2.05±0.05 ^b	2.34±0.02 ^a

Means ± SD from triplicate determinations with different superscript letters in the same row indicate significant differences ($p < 0.05$).

Table 3. The contents of β -carotene and β -tocopherol ($\mu\text{g/g}$ dry weight) in brown perilla and white perilla seeds.

Samples	β -carotene	β -tocopherol
Brown perilla seed	0.62±0.02	10.14±0.37 ^a
White perilla seed	ND	1.85±0.07 ^b

Means ± SD from triplicate determinations with different superscript letters in the same column indicate significant differences ($p < 0.05$). ND = not detectable

Brown perilla seed had higher 5.5-fold α -tocopherol content than had white perilla seed ($p < 0.05$). Difference content of α -tocopherol in oilseed and other oil crops had been reported. The tocopherol or vitamin E in perilla seed was reported at 276.78 $\mu\text{g/g}$ [34]. The amount of α -tocopherol was positively correlated with fat content in perilla seed (Table 1). Principal function of α -tocopherol is being an antioxidant in plant cell, and it is also a powerful biological antioxidant. From the result, brown perilla seed is an interesting source for using as a health food development.

3.4 Lipid Composition and Fatty Acid Profiles

Both brown perilla and white perilla seeds contained triglyceride as a major lipid composition (93-97%) (Table 4). In addition, a little amount of monoglyceride was found in brown perilla seed (2.19%) and white perilla seed (6.08%). No diglyceride was found

in both perilla seeds.

The fatty acid profiles of both perilla seeds are shown in Table 5. Fatty acids of brown perilla and white perilla lipids were significantly different in terms of both quality and quantity ($p < 0.05$). The nine identified fatty acids in perilla seed lipid can be divided into saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA). Brown perilla seed lipid had higher content of fatty acids than white perilla seed. The ratio of SFA, MUFA and PUFA was approximately 1.00:1.22:7.89 and 1.00:1.37:8.30 for brown perilla seed and white perilla seed lipids, respectively. Also, Siriamornpun *et al.* [6] and Ding *et al.* (2012) [35] reported that the SFA: MUFA: PUFA ratio of perilla seed was 1:1.10:7.76, and 1.00:2.00:6.02, respectively. From the results, the predominant unsaturated fatty acid of both perilla lipids was polyunsaturated fatty acid. Considering the MUFA, oleic acid was a major fatty acid

found in brown perilla lipid (11.81%) and white perilla lipid (11.18%), which was similar to Siriamornpun *et al.* [6] and Peiretti [36]. Predominant PUFA of both perilla lipids was α -linolenic acid, followed by γ -linolenic acid. Linolenic acid in brown perilla and white perilla lipids was 59.08% and 50.79%, respectively. Kanchanamayoon and Kanenil [5] also reported that the highest content of α -linolenic acid was found in perilla seed. In general, linolenic acid is considered as an essential fatty acid. Additionally, α -linolenic acid (18.87% in brown perilla lipid and 17.93% in white perilla lipid) and eicosadienoic acid (0.13% in brown perilla lipid and 0.14% in white

perilla lipid) were also found.

According to nutritional quality, the $n6$ and $n3$ ratio is important to lipid metabolism. The ratios of $n6:n3$ fatty acid of brown perilla and white perilla seeds were 0.32 and 0.35, respectively (Table 5). The results were similar to the ratio (0.3-0.4) in perilla lipid which was consistent with the previous reports by Siriamornpun *et al.* [6]. From the results, brown perilla seed could be used as a source of α -linolenic acid for dietary enrichment. However, the α -linolenic acid is very susceptible to oxidation and the seed handling and storage must be done carefully to avoid oil rancidity and off-flavor development.

Table 4. Lipid compositions of brown perilla and white perilla seeds.

Composition(% of total lipid)	Brown perilla seed	White perilla seed
Triglyceride	97.81	93.92
Diglyceride	ND	nd
Monoglyceride	2.19	6.08

ND = not detected

Table 5. Fatty acid compositions (g/100 g lipid) of brown perilla and white perilla seeds.

Fatty acids	Brown perilla seed	White perilla seed
Saturated fatty acid		
Palmitic acid	6.33 $\pm$ 0.01 ^a	5.54 $\pm$ 0.00 ^b
Stearic acid	3.22 $\pm$ 0.00 ^a	2.57 $\pm$ 0.00 ^b
Heneicosanoic acid	0.22 $\pm$ 0.00 ^a	0.19 $\pm$ 0.00 ^b
Behenic acid	0.12 $\pm$ 0.00	ND
Monounsaturated fatty acid		
Oleic acid	11.81 $\pm$ 0.01 ^a	11.18 $\pm$ 0.00 ^b
Eicosenoic acid	0.22 $\pm$ 0.00 ^a	0.17 $\pm$ 0.00 ^b
Polyunsaturated fatty acid		
γ -linolenic acid	18.87 $\pm$ 0.01 ^a	17.93 $\pm$ 0.01 ^b
α -linolenic acid	59.08 $\pm$ 0.02 ^a	50.79 $\pm$ 0.01 ^b
Eicosadienoic acid	0.13 $\pm$ 0.00 ^a	0.14 $\pm$ 0.01 ^a
Total saturated fatty acid (SFA)	9.89	8.30
Total monounsaturated fatty acid (MUFA)	12.03	11.35
Total polyunsaturated fatty acid (PUFA)	78.08	68.86
Total unsaturated fatty acid	90.11	80.21
Total fatty acid	100.00	88.51
SFA:MUFA:PUFA	1.00:1.22:7.89	1.00:1.37:8.30
$n6$ PUFA	19.00	18.07
$n3$ PUFA	59.08	50.79
$n6/n3$ PUFA ratio	1: 3.1 (0.32)	1:2.81 (0.36)

Means $\pm$ SD from triplicate determinations with different superscripts letters in the same row indicate significant differences ($p < 0.05$). ND = not detected

3.5 Bioactive Compounds

Total phenolic, flavonoid and flavonol contents from the extracts of brown perilla and white perilla seeds are shown in Table 6. Generally, brown perilla seed extract contained higher total phenolic, total flavonoid and total flavonol contents than white perilla seed extract ($p < 0.05$). Brown perilla seed extract exhibited slightly higher total phenolic content than white perilla seed. Total flavonoid and total flavonol contents of brown perilla seed extract was 27 folds and 500 folds greater than those of white perilla seed extract, respectively. Brown perilla seed extract has been reported for its bioactivity [15]. Total flavonoid content of brown perilla and white perilla seed extracts were 196.96 $\mu\text{g QE/g dry weight}$ and 7.28 $\mu\text{g QE/g dry weight}$, respectively. Similarly, total flavonol content were found to be 225.20 $\mu\text{g QE/g dry weight}$ and 0.45 $\mu\text{g QE/g dry weight}$ for brown perilla and white perilla seed extracts, respectively. Both, flavonoids and flavonols have been reported to possess a broad spectrum of chemical and biological activity such as radical scavenging property. From the results, brown perilla seed extract was an alternative source of bioactive compounds, especially flavonoids and flavonols.

3.6 Antioxidant Activities

3.6.1 DPPH-radical scavenging activity

Antioxidative activities of the extracts from perilla seeds, brown perilla and white perilla, are shown in Table 7. Both samples exhibited different antioxidant activity as measured by DPPH-radical scavenging activity ($p < 0.05$). The results showed that DPPH-radical scavenging activity of brown perilla seed extract was higher than that of white perilla seed ($p < 0.05$). The DPPH radical scavenging activity of extract from brown perilla seed was 3.7 folds greater

than that from white perilla seed. As a result, the DPPH radical scavenging activity assay suggested that brown perilla seed could act as hydrogen donors more effectively than white perilla seed one. The values obtained from DPPH-radical scavenging capacity corresponded well to the contents of the β -carotene, α -tocopherol (Table 3), total phenolics, total flavonoids, and total flavonols (Table 6) composed in the extracts.

3.6.2 ABTS-radical scavenging activity

The extracts from brown perilla and white perilla seeds are able to quench ABTS radicals (Table 7). The results showed that the extract from brown perilla seed was 10 times higher in ABTS-radical scavenging activity than that from white perilla seed. ABTS assay is an excellent tool for determining the antioxidative activity, in which the radical is quenched to form ABTS-radical complex. It is also widely employed for measuring the relative radical scavenging activity of hydrogen donating and chain breaking antioxidants in many plant extracts. Sargi *et al.* [37] reported that antioxidant capacity (ABTS^{•+} assay) of *Perilla frutescens* L. was 4.06 and 3.32 mmol Trolox equivalent antioxidant capacity/g sample for brown perilla and white perilla seeds, respectively. As the obtained results, the ABTS-radical scavenging capacity correlated well with the contents of the β -carotene, α -tocopherol (Table 3), total phenolics, flavonoids and flavonols (Table 6).

3.6.3 Ferric reducing antioxidant power (FRAP)

FRAP of brown perilla and white perilla seed extracts is presented in Table 7. The results showed that FRAP of both samples was slightly different ($p < 0.05$). This indicated that perilla seed extract contained certain compounds which can reduce FRAP reagent from ferric to ferrous form and thus

they are regarded as antioxidant. As the results obtained, brown perilla seed extract showed the pronounced effect in donating electrons, in which propagation of lipid oxidation could be retarded. Flavonoids can inhibit metal-initiated lipid oxidation by forming

complexes with metal ions [38]. Therefore, the extracts from both brown perilla and white perilla seeds exhibited ferric reducing ability, suggesting the capability to react with free radicals, especially ferric ion, and finally to terminate the oxidative chain reaction.

Table 6. Bioactive compounds of brown perilla and white perilla seeds.

Bioactive compounds	Brown perilla seed	White perilla seed
Total phenolic content(mg GAE/g dry weight)	2954±217.32 ^a	1290.24±112.55 ^b
Total flavonoids content(µg QE/g dry weight)	196.96±0.34 ^a	7.28±0.08 ^b
Total flavonols content(µg QE/g dry weight)	225.20±0.67 ^a	0.45±0.13 ^b

Means ± SD from triplicate determinations with different superscripts letters in the same row indicate significant differences ($p < 0.05$).

Table 7. Antioxidant activity of brown perilla and white perilla seeds.

Antioxidant activity	Brown perilla seed	White perilla seed
DPPH (% scavenging)	77.83 ± 0.58 ^a	20.86 ± 0.26 ^b
ABTS (µmolTrolox/g dry weight)	3.70 ± 0.01 ^a	0.36 ± 0.00 ^b
FRAP (µmolTrolox/g dry weight)	2.46 ± 0.03 ^a	2.26 ± 0.02 ^b
Reducing power(BHT equivalent/100 g dry weight)	0.47 ± 0.01 ^a	0.26 ± 0.00 ^b

Means ± SD from triplicate determinations with different superscripts letters in the same row indicate significant differences ($p < 0.05$).

3.6.4 Reducing power

To confirm the reducing capacity of perilla seed extracts, the reducing power reported as BHT equivalent was performed. Reducing power of extracts from brown perilla and white perilla seeds is shown in Table 7. Generally, the reducing power of brown perilla seed extract was 2 times higher than that from white perilla seed extract ($p < 0.05$). This result was somehow different with the FRAP value in which FRAP of both samples was slightly different (Table 7). Directed correlation between antioxidant activity and reducing power of certain plant extracts has been reported [39,40]. The reducing properties are generally associated with the presence of reductones [39], which have been shown to exert

antioxidant action by breaking the free radical chain by donating a hydrogen atom [41]. Reductones may occur during the drying process via the Maillard reaction and a greater content of reductones could be found in brown perilla seed extract. Therefore, higher reducing power of brown perilla seed extract would contribute to higher bioactivity of chemical compounds composed in the seed.

4. CONCLUSION

Nutritional characteristics of brown perilla and white perilla seeds were significantly different. Both perilla seeds exhibited differences in chemical compositions, particularly fat and carbohydrate. Higher protein, fat, ash, crude fiber, β -carotene and

α -tocopherol contents were found in brown perilla seed whereas higher carbohydrate content was observed in white perilla seed. Additionally, brown perilla lipid contained high total unsaturated fatty acid, especially essential fatty acid, α -linolenic acid (C18:3). For certain bioactive compounds, brown perilla seed had higher contents of total phenolic, total flavonoids, and total flavonols than white perilla seed. As a result, brown perilla seed extract showed better scavenging activities against DPPH radicals, ABTS radicals than white perilla seed extract. Also, brown perilla seed extract had a superior FRAP and reducing power to white perilla counterpart. Therefore, brown perilla seed can be used as a functional ingredient for functional food production.

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