Exploration of the Antioxidant Chemical Constituents and Antioxidant Performance of Various Solvent Extracts of Eighteen Plants

Semeneh Seleshe, Ammara Ameer, and Suk Nam Kang

Department of Animal Resource, Daegu University, Gyeongbuk 38453, Korea

ABSTRACT: This study examined the antioxidant chemical constituents (total phenolic and total flavonoid contents) and antioxidant activities [1,1-diphenyl-2-picrylhydrazyl (DPPH) and 2,2’-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) radical scavenging, and ferric reducing antioxidant power (FRAP)] of different solvent extracts of eighteen functional plants. The active components of the target plants were extracted using four different solvents (methanol, ethanol, chloroform, and water). *Mentha piperascens* leaf exhibited a higher total phenolic content (chloroform and water extracts), total flavonoid content (all solvent extracts), DPPH radical scavenging activity (methanol, ethanol, and water extracts), ABTS radical scavenging activity (water extract), and FRAP radical scavenging activity (water extract) (in all solvent extracts). Similarly, *Petasites japonicas* root was another excellent and competent extract with a high total flavonoid content (in all four solvent extracts), DPPH and ABTS radical scavenging activity (methanol, ethanol, and water extracts), and FRAP activity (methanol, ethanol, and water extracts) (in all solvent extracts). *Rubus coreanus* fruit had the highest total phenolic content (methanol, ethanol, and water extracts), DPPH and ABTS radical scavenging activate (in all solvent extracts), and FRAP in its water extract were the two most effective functional plants. Based on the abundance of antioxidant chemical constituents and the most potent antioxidant activity demonstrated in this study, extracts from *M. piperascens* leaf, *P. japonicas* root, and *R. coreanus* fruit appear to be promising candidates to meet the current demand for natural preservatives in food and pharmaceutical industries.

Keywords: antioxidant, natural preservatives, radical scavenging, solvent

INTRODUCTION

Food quality degradation during storage is a critical issue for the food industry (Nychas and Panagou, 2011). Food spoilage occurs when a food product undergoes microbiological, chemical, or physical changes that render it unfit for consumption (Petruzzi et al., 2017). Oxidation is an important driver of foodstuff deterioration (Nychas and Panagou, 2011). The oxidation process alters numerous interactions between food ingredients, resulting in unpleasant products (Ahmed et al., 2016). Moreover, food lipids are particularly susceptible to oxidation, and their degradation reactions are a frequent cause of food degradation during processing, storage, distribution, and final preparation (Ahmed et al., 2016). Rancidity can manifest itself in various forms, including off-flavors, color loss, altered nutrient value, and the production of toxic substances (Keller et al., 2015; Li et al., 2015). Moreover, mutagenic, carcinogenic, and cytotoxic lipid oxidation products are considered health risk factors (Keller et al., 2015; Li et al., 2015).

Certain preservatives are used by food manufacturers to extend the shelf life and maintain the quality of food products (Sharma, 2015; Kumari et al., 2019). Preservatives are natural or synthetic substances added to foods to keep them from spoiling due to microbial growth or undesirable chemical changes (Kumari et al., 2019). Presently, most preservatives are synthetic rather than natural (Anand and Sati, 2013). Antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and propyl gallate are added to foods to protect them from oxidation (Kumari et al., 2019).

In recent years, artificial/synthetic preservatives have raised various health concerns (Saeed et al., 2019). Many of these preservatives are thought to be toxic (Kumari et al., 2019), while others can be fatal (Anand and Sati, 2013).
Exploration of Potential Antioxidant Plants

MATERIALS AND METHODS

Collection of functional plants
Approximately 120 different functional plants regarded as potential natural preservatives were collected from the National Institute of Biological Resources for use in the current study (Incheon, Korea). For 7 days at 50°C, the plant parts were oven-dried (10–15% moisture content). Samples were collected in polyethylene plastic bags at the experimental site: Daegu University’s Life and Natural Science College. A preliminary screening of the antioxidant constituents and activities of 120 different functional plants was conducted before the study. Ethanol and water are food-grade solvents that are non-toxic (required no additional purification steps) and can be used directly as food preservatives. Therefore, ethanolic extracts of functional plant parts were chosen for screening, and their total phenolic content [mg catechin (CAT) equivalents/g] and DPPH radical scavenging activity (mg BHA equivalents/g) were determined. Subsequently, 18 functional plants with a higher total phenolic content (>0.15 mg CAT equivalents/g) and DPPH radical scavenging activity (>125 mg BHA equivalents/g) were chosen for the subsequent and actual study. These screening cut points were chosen considering the extract’s performance variability. Those plants not selected for the actual study were below the cutoff value (the cut points), indicating no noticeable variation.

Measurement of total phenolic content
The total phenolic content was determined using the Folin-Ciocalteu reagent as described by Singleton and Rossi (1965), with some modifications. Briefly, samples were prepared from various solvent extracts of the functional plants used in this study at various concentrations (50, 100, 200, 300, 400, and 500 μg/mL). Next, 20 μL of the extracted sample was added to 100 μL of distilled water and incubated for 5 min with 20 μL of Folin-Cio-
calteu reagent (Sigma-Aldrich Co., St. Louis, MO, USA). After 30 min of incubation at room temperature, 10 μL of 20% sodium carbonate (Na2CO3) was added to the reaction mixture. The absorbance at 760 nm was measured spectrophotometrically. Catechin was used as a reference standard, and the sample readings were expressed as mg CAT equivalents/g dry weight.

**Measurement of total flavonoid content**

The total flavonoid content was determined using a modified version of the Meda et al. (2005) method. In brief, 0.25 mL of sample (1 mg/mL) was added to 1 mL of double-distilled water in a tube. Next, 0.075 mL of 5% NaNO2, 0.075 mL of 10% AlCl3, and 0.5 mL of 1 M NaOH were added sequentially at 0, 5, and 6 min. Finally, the reacting solution was adjusted to a volume of 2.5 mL using double-distilled water. A spectrophotometer was used to determine the solution’s absorbance at 410 nm (Ultrspec 2100 pro, Amersham Pharmacia Biotech Inc., Piscataway, NJ, USA). Rutin was used as a standard to determine the total flavonoid content. The results are given as mg rutin equivalents (RE)/g dry weight.

**DPPH radical scavenging activity**

The samples’ DPPH free radical scavenging activity was determined using a method adapted from Brand-Williams et al. (1995). For the current study, samples from various solvent extracts of the functional plants were prepared into various concentrations [(0, control), 50, 100, 200, 300, 400, and 500 μg/mL] using 70% ethanol. The study used 0.1 mM DPPH in ethanol. Then, each sample was mixed in a 1:1 ratio with the DPPH solution. The mixture was vigorously shaken and left for 30 min, and the absorbance was measured spectrophotometrically at 517 nm. Reduced absorbance of the reaction mixture indicates increased free radical scavenging efficiency. The following equation was used to determine the DPPH free radical scavenging capacity. BHA was used as the standard. The results were expressed as BHA equivalent antioxidant capacity based on the mean of three readings.

\[
\text{Scavenging activity (\%) = } \frac{\text{Control absorbance} - \text{Sample absorbance}}{\text{Control absorbance}} \times 100
\]

**ABTS radical scavenging assay**

The ABTS radical scavenging activity of extracts was determined using a modified version of the method described by Re et al. (1999). To prepare ABTS-potassium persulfate solution (ABTS+), 7 mM ABTS was mixed with 2.45 mM potassium persulfate (2:1, v/v). For approximately 16 h, the ABTS radical cations were incubated at 20°C. By diluting the solution with 95% (v/v) ethanol, the absorbance of the solution was adjusted to 0.70±0.02 at 734 nm. Samples were prepared from various solvent extracts of functional plants at various concentrations [(0, control), 50, 100, 200, 300, 400, and 500 μg/mL]. The sample and ABTS+ solution were then mixed (1:1, v/v), and the mixture’s absorbance at 734 nm was monitored after 6 min. In place of the sample, 95% (v/v) ethanol was used as the blank, each sample was measured in triplicate, and BHT was used as a reference compound. The percentage of inhibition was calculated in the formula indicated below. The results were expressed as BHT equivalent antioxidant capacity based on the mean of three readings:

\[
\text{Inhibition (\%) = } \frac{\text{Control absorbance} - \text{Sample absorbance}}{\text{Control absorbance}} \times 100
\]

**FRAP assay**

The antioxidant activity of extracts against ferric reduction was determined using the FRAP assay developed by Benzie and Strain (1996). The FRAP method determines the difference in absorbance that occurs when the complex 2,4,6-tripyridyl-S-triazine (TPTZ)-Fe3+ is reduced to TPTZ-Fe2+ (colored form) in the presence of antioxidants (Halvorsen et al., 2002). 25 mL of 300 mmol/L acetate buffer, 2.5 mL of 10 mmol/L TPTZ in 40 mmol/L HCl, and 2.5 mL of 20 mmol/L FeCl3·6H2O were combined to produce the solution for this assay (solutions were mixed together 10:1:1 ratio). We prepared samples from various solvent extracts of selected functional plants at concentrations ranging from 50 to 500 μg/mL. Subsequently, the extracted sample, distilled water, and FRAP reagent were mixed in a 1:3:30 ratio and absorbance measurements at 593 nm were taken during the 5-min reaction. The calibration curve was plotted for various concentrations of Fe(II) (501,000 μM), with quercetin serving as the standard. The average of three readings was calculated and expressed as mg of quercetin equivalents (QE)/g ferric reducing activity.

**Statistical analysis**

The current study compared different solvent extracts of the same plant part and the same solvent extracts of different target plants. The experimental data were statistically analyzed using one-way ANOVA with SAS software version 9.4 (SAS Institute, Cary, NC, USA). A significance level of P<0.05 was used for all evaluations; Duncan’s multiple range tests were used to detect differences between means.

**RESULTS AND DISCUSSION**

The present study examined the antioxidant properties
The total phenolic content of methanolic extracts ranged from 0.10 to 2.69 mg CAT equivalents/g, a variation of approximately thirty-six-fold. Compared to the other solvent types, methanolic extracts of *Cornus officinalis* fruit, *Cudraria tricuspidata* fruit, *Lepidium sativum* seed, and *Moringa stenopetala* leaf exhibited a significantly highest total phenolic content in mg CAT equivalents/g. Altogether, phenolic compounds extraction potential of solvents, methanol > ethanol > chloroform > water had 10, 7, 4, and 1 active extracts, respectively, in 18 target plants considered. There is a significant (P<0.05) difference in the total phenolic content of four solvent extracts from different plants used in the current study (Table 1).

The total phenolic content of methanolic extracts ranged between 0.10 and 3.58 mg CAT equivalents/g, a variation of approximately thirty-six-fold. Compared to the other 18 plants analyzed in this study, the following seven plants, the total phenolic content varied significantly (P<0.05) between different solvent extracts of a plant part. Different solvent systems have varying degrees of polarity, resulting in significant differences in the extraction of active compounds. Compared to their counterparts, plant extracts, methanolic extracts of *Cornus officinalis* fruit, *Cudraria tricuspidata* fruit, *Lepidium sativum* seed, *Morus bombycis* fruit, *Paeonia lactiflora* root, *Pinus densiflora* needle, and *Scutellaria baicalensis* root, ethanolic extracts of *Caragana sinica* leaf, *Liriope platyphylla* stem, *Petasites japonicus* root, and *Rubus coreanus* fruit, chloroform extract of *Lonicera japonica* leaf, and water of *Mentha piperascens* leaf and *Moringa stenopetala* leaf, both methanolic and ethanolic *Poncirus trifoliata* fruit and *Taraxacum coreanum* flower, both methanolic and water extracts of *Zanthoxylum piperitum* seed, and *Brassica juncea* seed of both ethanolic and water extracts exhibited a significantly highest total phenolic content in mg CAT equivalents/g. Altogether, phenolic compounds extraction potential of solvents, methanolic > ethanolic > water > chloroform had 10, 7, 4, and 1 active extracts, respectively, in 18 target plants considered. There is a significant (P<0.05) difference in the total phenolic content of four solvent extracts from different plants used in the current study (Table 1).

The total phenolic content of methanolic extracts ranged between 0.10 and 3.58 mg CAT equivalents/g, a variation of approximately thirty-six-fold. Compared to the other 18 plants analyzed in this study, the following seven

| Explored plant | Methanol | Ethanol | Chloroform | Water | SEM |
|---------------|---------|---------|------------|-------|-----|
| *Brassica juncea* seed | 0.28<sup>Bb</sup> | 0.51<sup>Ad</sup> | 0.33<sup>Ba</sup> | 0.74<sup>Ae</sup> | 0.13 |
| *Caragana sinica* leaf | 0.75<sup>EF</sup> | 0.99<sup>ACde</sup> | 0.34<sup>Cd</sup> | 0.79<sup>Ba</sup> | 0.08 |
| *Cornus officinalis* fruit | 0.28<sup>EF</sup> | 0.30<sup>F</sup> | 0.18<sup>BF</sup> | ND | 0.04 |
| *Cudraria tricuspidata* fruit | 1.99<sup>EF</sup> | 0.39<sup>EF</sup> | 0.29<sup>BF</sup> | 0.15<sup>Cb</sup> | 0.07 |
| *Lepidium sativum* seed | 1.30<sup>EF</sup> | 1.42<sup>EF</sup> | 0.14<sup>Ch</sup> | 0.9<sup>Fb</sup> | 0.13 |
| *Liriope platyphylla* stem | 0.13<sup>EF</sup> | 0.19<sup>F</sup> | 0.05<sup>CI</sup> | ND | 0.01 |
| *Loniceraja japonica* leaf | 0.61<sup>EF</sup> | 0.64<sup>EF</sup> | 0.67<sup>Bb</sup> | 0.47<sup>Cb</sup> | 0.03 |
| *Mentha piperascens* leaf | 0.61<sup>EF</sup> | 1.16<sup>CD</sup> | 0.44<sup>C</sup> | 1.27<sup>AC</sup> | 0.05 |
| *Moringa stenopetala* leaf | 0.65<sup>T</sup> | 1.16<sup>CD</sup> | 1.12<sup>BA</sup> | 1.08<sup>BI</sup> | 0.09 |
| *Morus bombycis* fruit | 1.95<sup>EF</sup> | 1.22<sup>EF</sup> | 1.22<sup>BA</sup> | 1.08<sup>BI</sup> | 0.09 |
| *Paeonia lactiflora* root | 2.69<sup>EF</sup> | 1.24<sup>CD</sup> | 0.17<sup>ACb</sup> | ND | 0.09 |
| *Petasites japonicus* root | 0.10<sup>T</sup> | 0.62<sup>EF</sup> | 0.31<sup>Bb</sup> | 0.14<sup>bh</sup> | 0.07 |
| *Pinus densiflora* needle | 3.49<sup>EF</sup> | 2.71<sup>EF</sup> | 1.11<sup>Ca</sup> | 0.34<sup>bh</sup> | 0.22 |
| *Poncirus trifoliata* fruit | 0.61<sup>F</sup> | 0.45<sup>EF</sup> | 0.32<sup>Cd</sup> | 0.45<sup>Cb</sup> | 0.07 |
| *Rubus coreanus* fruit | 3.58<sup>EF</sup> | 5.39<sup>EF</sup> | 0.29<sup>Cd</sup> | 4.79<sup>Ah</sup> | 0.56 |
| *Scutellaria baicalensis* root | 1.63<sup>EF</sup> | 1.38<sup>EF</sup> | 0.51<sup>CC</sup> | 1.81<sup>AB</sup> | 0.13 |
| *Taraxacum coreanum* flower | 0.73<sup>F</sup> | 0.72<sup>EF</sup> | 0.24<sup>EF</sup> | 0.62<sup>EF</sup> | 0.10 |
| *Zanthoxylum piperitum* seed | 0.32<sup>T</sup> | 0.27<sup>EF</sup> | 0.21<sup>EF</sup> | 0.33<sup>EF</sup> | 0.02 |
| SEM | 0.10 | 0.29 | 0.05 | 0.12 |
plants had significantly (P<0.05) higher total phenolic compounds in methanolic extracts, in the following order: *R. coreanus* fruit, *P. deniflora* needle > *P. lactiflora* root > *C. tricuspidata* fruit, *M. bombycis* fruit > *S. baicalensis* root > *L. sativum* seed having the content of 3.58, 3.49, 2.69, 1.99, 1.95, 1.63, and 1.30 mg CAT equivalents/g, respectively. The lowest content of <0.20 mg CAT equivalents/g is exhibited in the *L. platyphylla* stem and *P. japonicus* root extracts. From ethanolic extracts, substantially (P<0.05) highest levels of total phenolic compounds were exhibited in the following seven plants in decreasing order: *R. coreanus* fruit > *P. deniflora* needle > *L. sativum* seed and *S. baicalensis* root > *P. lactiflora* root, *M. bombycis* fruit, and *M. stenopetala* leaf with 5.39, 2.71, 1.42, 1.38, 1.24, 1.22, and 1.16 mg CAT equivalents/g, respectively. Furthermore, the lowest contents <0.25 mg CAT equivalents/g were exhibited in the *Z. piperitum* root and *L. platyphylla* stem. The total phenolic content ranged from 0.19 to 5.39 mg CAT equivalents/g which is about 28-fold in variation, whereas the total phenolic compounds from chloroform solvent were markedly (P<0.05) higher in the following six plants: *M. bombycis* fruit and *P. deniflora* needle > *L. japonica* leaf > *S. baicalensis* root, *M. piperascens* leaf, and *M. stenopetala* leaf with the content of 1.12, 1.11, 0.67, 0.51, 0.46, and 0.44 mg CAT equivalents/g, respectively. The lowest content of <0.20 mg CAT equivalents/g was exhibited in *C. officinalis* fruit, *P. lactiflora* root, *L. sativum* seed, and *L. platyphylla* stem extracts. The content ranged from 1.12 mg CAT equivalents/g in *M. bombycis* fruit to 0.05 mg CAT equivalents/g in *L. platyphylla* stem, which resulted in a 22-fold variation. Furthermore, from the water extracts, the higher levels of total phenolic compounds were exhibited as follows: *R. coreanus* fruit > *S. baicalensis* root > *M. stenopetala* leaf > *M. bombycis* fruit, *L. sativum* seed, and *M. piperascens* leaf corresponding with 4.78, 1.81, 1.27, 1.08, 0.97, and 0.97 mg CAT equivalents/g, respectively. *P. lactiflora* root, *L. platyphylla* stem, and *C. officinalis* fruit water extracts did not possess total phenolic compounds in mg CAT equivalents/g.

### Total flavonoid content of explored plants

The phenolic compounds found in plants are classified into numerous categories. The most important are flavonoids, which exhibit significant antioxidant properties (Nunes et al., 2012). Flavonoids are found naturally in plants and are beneficial to human health. Flavonoid derivatives have been shown to have antibacterial, antiviral, anti-inflammatory, anticancer, and anti-allergic properties (Di Carlo et al., 1999; Montoro et al., 2005). Flavonoids are extremely effective at scavenging the majority of oxidizing chemicals, including singlet oxygen and other free radicals implicated in various diseases (Bravo, 1998). Table 2 summarizes the total flavonoid content of various solvent extracts of functional plants used in this study. Among the 18 plants analyzed in this study, a significant (P<0.05) difference in total flavonoid (mg RE/g) concentration was observed.

**Table 2. Total flavonoid content of various plant solvent extracts**

| Explored plant           | Methanol | Ethanol | Chloroform | Water |
|--------------------------|----------|---------|------------|-------|
| *Brassica juncea* seed   | ND       | ND      | ND         | ND    |
| *Caragana sinica* leaf   | 0.11ab   | 0.15ad  | ND         | ND    |
| *Cornus officinalis* fruit | ND    | ND  | 0.08a     | ND    |
| *Cudrania tricuspidata* fruit | ND   | ND  | ND         | ND    |
| *Lepidium sativum* seed  | 5.90a    | 5.17a   | 2.46b     | ND    |
| *Liriope platyphylla* stem | ND  | ND    | ND         | ND    |
| *Lonicera japonica* leaf  | ND     | ND     | ND         | ND    |
| *Mentha piperascens* leaf | 0.73bc | 1.55bc | 6.01a   | 1.32c  |
| *Moringa stenopetala* leaf | ND | ND | ND | ND |
| *Morus bombycis* fruit   | ND       | ND      | ND         | ND    |
| *Paeonia lactiflora* root | ND     | ND     | ND         | ND    |
| *Petasites japonicus* root | 0.35cd | 2.08ab | 0.60cd | 1.13b  |
| *Pinus deniflora* needle | ND       | ND      | ND         | ND    |
| *Poncirus trifoliata* fruit | ND | ND | ND | ND |
| *Rubus coreanus* fruit   | ND       | ND      | ND         | ND    |
| *Scutellaria baicalensis* root | ND | ND | ND | ND |
| *Taraxacum coronaria* flower | ND | ND | ND | ND |
| *Zanthoxylum piperitum* seed | 2.34bc | 0.04ad | 1.46bc | 0.28c  |
| **SEM**                  | 0.06     | 0.27    | 0.05       | 0.02  |

Means in a row (different solvent extracts of the same target plant) followed by uppercase letters (A-D) are significantly different (P<0.05).

Means in a column (the same solvent extracts of different target plants) followed by lowercase letters (a-e) are significantly different (P<0.05).

RE, rutin equivalents; SEM, standard mean error (n=3); ND, not detected.
tent was observed between their various solvent extracts in C. sinica leaf, C. officinalis fruit, L. sativum seed, M. piperascens leaf, P. japonicus root, S. baicalensis root, and Z. piperitum seed. In contrast, the rest of the plants did not own total flavonoid in mg RE/g for any solvents used in the extraction. Moreover, unlike their counter solvents extracts methanol extracts of L. sativum seed and Z. piperitum seed, ethanolic extracts of L. sativum seed and S. baicalensis root, and chloroform extracts of M. piperascens leaf and L. sativum seed exhibited a substantially (P<0.05) higher total flavonoid (mg RE/g) content. When the extraction potential of the solvents was considered in seven of the target plants with high total flavonoid content, ethanol was found to be superior to methanol. Chloroform was found to be superior to water (ethanol> methanol and chloroform> water), with 3, 2, and no active extracts, respectively.

Of the eighteen plants examined in the present study, the total flavonoid content of methanolic solvent extracts was exhibited in the following five plants and listed as L. sativum seed> Z. piperitum seed> M. piperascens leaf> P. japonicus root> C. sinica leaf having 5.90, 2.34, 0.73, 0.35, and 0.11 mg RE/g, respectively, and other extracts from methanolic solvent did not yield total flavonoid in mg RE/g. Similarly, a significantly (P<0.05) higher level of total flavonoid from ethanolic extracts was found in the following plants in decreasing order: S. baicalensis root and L. sativum seed> P. japonicus root> M. piperascens leaf having a content of 5.31, 5.17, 2.08, and 1.55 mg RE/g, respectively. Extracts from C. sinica leaf and Z. piperitum seed exhibited a noticeably (P<0.05) lower content<1 mg RE/g compared to the total flavonoid content of the other extracts in mg RE/g. The M. piperascens leaf> L. sativum seed> Z. piperitum seed extracts in total flavonoid content from chloroform extracts followed by P. japonicus root and C. officinalis fruit with contents of 6.01, 2.46, 1.46, 0.60, and 0.08 mg RE/g, respectively. Furthermore, we observed no total flavonoid content in mg RE/g in the other chloroform extracts. Water extracts of other plants examined, except for M. piperascens leaf, P. japonicus root, and Z. piperitum seed, did not produce a total flavonoid value in mg RE/g. The contents in the three indicated extracts were also limited to 1.32, 1.13, and 0.28 mg RE/g, respectively.

DPPH radical scavenging activity of explored plants

The free radical scavenging activity of DPPH has been widely used to determine the antioxidant activity of natural products derived from plants and microbes (Shyur et al., 2005). The DPPH assay has several advantages over other methods, including increased stability, credible sensitivity, ease of use, and feasibility (Ozcelik et al., 2003). Furthermore, the assay determines an extract’s ability to donate hydrogen to the DPPH radical, thereby bleaching the DPPH solution; the greater the bleaching action, the higher the antioxidant activity (Prabhune et al., 2013).

### Table 3. DPPH radical scavenging activity of various plant solvent extracts

| Explored plant                              | Methanol | Ethanol | Chloroform | Water | SEM |
|---------------------------------------------|----------|---------|------------|-------|-----|
| Brassica juncea seed                        | 358.18a  | 281.05a | 101.58b    | 239.70de | 9.12 |
| Caragana sinica leaf                        | 231.45bh | 324.48b | 80.00c     | 222.70ed | 9.80 |
| Cornus officinalis fruit                    | 415.87a  | 380.06a | 37.84c     | ND    | 14.34 |
| Cudraria tricuspidata fruit                 | 353.55b  | 209.55b | 116.84c    | 192.48d  | 9.15 |
| Lepidium sativum seed                       | 275.23ab | 477.33ab| 119.61d    | 322.59bc | 16.84 |
| Liriope platyphylla stern                   | 97.19c   | 130.33c | 165.78ad   | ND     | 4.36 |
| Lonicera japonica leaf                      | 397.98cd | 419.81bc| 310.95c    | 258.82cd | 8.68 |
| Mentha piperascens leaf                     | 498.67ab | 413.32bc| 119.15c    | 479.15ab | 18.45 |
| Moringa bombycis fruit                      | 351.45ab | 321.64bf| 96.92e     | 344.51bc | 7.34 |
| Morus bombycis fruit                        | 304.99bf | 249.78chi| 378.46ab   | 214.16ghi| 13.76 |
| Paonia lactiflora root                      | 537.41a  | 492.41a | 177.33cd   | ND     | 14.55 |
| Petasites japonicus root                    | 487.56ab | 490.06ab| 127.19ef   | 501.01ab | 16.55 |
| Pinus densiflora needle                     | 508.27ab | 357.88abd| 289.98ec   | 149.13d  | 6.13 |
| Pongcirus trifoliata fruit                  | 239.14ah | 240.09ah| 148.25be   | 209.01ghi| 17.85 |
| Rubus coreanus fruit                        | 514.45abc| 465.70bf| 171.30cd   | 502.65ab | 11.95 |
| Scutellaria baicalensis root                | 451.51abc| 344.42def| 146.55ce   | 487.14ab | 23.23 |
| Taraxacum coreanum flower                   | 303.80df | 323.89bf| 118.77ce   | 395.83bc | 21.00 |
| Zanthoxylum piperitum seed                  | 220.10ch | 269.22gh| ND         | 245.30bcd | 11.40 |

Means in a row (different solvent extracts of the same target plant) followed by uppercase letters (A-D) are significantly different (P<0.05).

Means in a column (the same solvent extracts of different target plants) followed by lowercase letters (a-k) are significantly different (P<0.05).

DPPH, 1,1-diphenyl-2-picrylhydrazyl; BHA, butylated hydroxyanisole; SEM, standard mean error (n=3); ND, not detected.
Table 3 summarizes the DPPH radical scavenging antioxidant activity of various solvent extracts of explored plants. The type of solvent used in the extraction had a significant \((P<0.05)\) effect on the DPPH radical scavenging activity in all eighteen plants examined. The stability of different extracts from the same plant material is determined by the solvent used to extract the active components, and antioxidant concentrations and activity of extracts from the same plant material can vary significantly (Akowuah et al., 2005). Compared to their counter solvents, a noticeably \((P<0.05)\) strong DPPH radical scavenging activity was observed in methanolic extracts of B. juncea seed, C. officinalis fruit, C. trifurcata fruit, P. lactiflora root, and P. deniflora needle, ethanolic extracts of C. sinica leaf, L. sativum seed, L. japonica leaf, and Z. piperitum seed, chloroform extracts of L. platyphyllea stem and M. bombycis fruit, and water extract of the T. coreanum flower. Similarly, we observed markedly potent DPPH radical scavenging activity in both methanolic and water extracts of M. piperascens leaf, M. stenopetala leaf, R. coreanus flower, and S. baicalensis root. Methanolic, ethanolic, and chloroform extracts of P. japonicus root and P. trifoliata fruit had a similar highest \((P<0.05)\) DPPH radical scavenging activity than their water extracts. Based on the scavenging potential of solvents we observed an increasing trend: methanol > water > ethanolic > chloroform with 11, 7, 6, and 2 potent extracts, respectively.

Among 18 target plants considered in this study, the following five plants exhibited the most effective \((P<0.05)\) DPPH radical scavenging activity from methanolic extracts and ranked as P. lactiflora root > R. coreanus fruit and P. deniflora needle > M. piperascens leaf and P. japonicus root having the scavenging values of 537.41, 514.45, 508.27, 498.67, and 487.56 mg BHA equivalents/g, respectively. All other extracts exhibited similar DPPH scavenging values above 220.00 mg BHA equivalents/g except for L. platyphyllea stem, which had the least score of 97.19 mg BHA equivalents/g. Similarly, the L. platyphyllea stem ethanolic extracts had the least scavenging activity for DPPH radical with 130.33 mg BHA equivalents/g. Meanwhile, all other ethanolic extracts presented scavenging activity above 200.00, and substantially \((P<0.05)\) higher DPPH radical scavenging activity was observed in the following six plants in decreasing order: P. lactiflora root > P. japonicus root and L. sativum seed > R. coreanus fruit > L. japonica leaf and M. piperascens leaf with corresponding values of 492.41, 490.06, 477.33, 465.70, 419.81, and 413.32 mg BHA equivalents/g, respectively. M. bombycis fruit, L. japonica leaf, P. deniflora needle, P. lactiflora root, R. coreanus fruit, and L. platyphyllea stem exhibited noticeably \((P<0.05)\) effective DPPH radical scavenging from chloroform extracts with 378.46, 310.95, 289.98, 177.33, 171.30, and 165.78 mg BHA equivalents/g, respectively. C. officinalis fruit extracts exhibited the least scavenging activity of 37.84 mg BHA equivalents/g, and Z. piperitum seed exhibited significant DPPH radical scavenging activity. Moreover, from water extracts, high DPPH radical scavenging activity \((P<0.05)\) \((>395.00\text{ mg BHA equivalents/g})\) was observed in the following five listed extracts in decreasing order: R. coreanus fruit, P. japonicus root, S. baicalensis root, and M. piperascens leaf, T. coreanum flower, and their scavenging values were 502.65, 501.01, 487.14, 479.15, and 395.83 mg BHA equivalents/g, respectively. However, the water extracts of three plants, namely P. lactiflora root, L. platyphyllea stem, and C. officinalis fruit, did not show scavenging activity for DPPH radical in mg BHA equivalents/g.

**ABTS radical scavenging activity of explored plants**

The ABTS radical cation scavenging assay is widely used to determine the radical scavenging ability of samples (Brand-Williams et al., 1995; Ilyasov et al., 2020). Due to the ease with which this procedure can be applied, it is frequently used to rapidly determine the antioxidant activity of various plant extracts (Prior et al., 2005). Single-electron transfer deactivates radicals in the ABTS assay. When ABTS reacts with potassium persulfate, the ABTS*• chromophore is formed, converting ABTS to its radical cation. This radical cation is blue in color and absorbs light at a wavelength of 734 nm (Re et al., 1999). The antioxidant activity of different solvent extracts of functional plants considered in this study was summarized in Table 4. In all 18 plants examined in this study, there is a significant \((P<0.05)\) difference in ABTS radical scavenging activity between their various solvent extracts. In comparison to their counter solvent extracts, methanolic extracts exhibited significantly \((P<0.05)\) increased ABTS radical scavenging activity of C. trifurcata fruit, L. sativum seed, M. bombycis fruit, P. lactiflora root, and P. deniflora needle, and ethanolic extracts of C. sinica leaf, C. officinalis fruit, L. platyphyllea stem, L. japonica leaf, and S. baicalensis root, and water extracts of M. piperascens leaf, P. japonicus root, and T. coreanum flower. Moreover, the methanolic and ethanolic extracts of P. trifoliata fruit, methanolic and water extracts of Z. piperitum seed, and chloroform and water extracts of B. juncea seed exhibited a noticeably \((P<0.05)\) more potent ABTS radical scavenging activity than their counter solvent extracts. Likewise, the methanolic, ethanolic, and water extracts of M. stenopetala leaf and R. coreanus fruit exhibited markedly stronger \((P<0.05)\) ABTS radical scavenging activity than their counter chloroform extracts. The effectiveness of the solvents in ABTS radical scavenging activities was determined by the number of their extracts giving rise to significantly strong activity from the 18 selected plants and ranked as methanol > ethanol extract > water extract > chloroform by having 9, 8, 7, and 1 active extracts, respectively.
Based on these results, we identified seven effective plants in the ABTS radical scavenging ability from methanolic extract: *R. coreanus* fruit and *P. lactiflora* root, *C. tricuspidata* fruit, *P. deniflora* needle, *M. bombycis* fruit, *L. sativum* seed and *P. japonicus* root exhibiting the scavenging values of 239.46, 233.49, 213.87, 195.45, 182.65, 163.62, and 155.84 mg BHT equivalents/g, respectively. The *L. platyphylla* stem extract exhibited the least scavenging ability of <30 mg BHT equivalents/g, and the variation among methanolic extracts was approximately 40-fold. Among the ethanolic extracts, the most effective (*P<0.05*) plants exhibiting ABTS radical scavenging ability were: *R. coreanus* fruit, *S. baicalensis* root, *P. lactiflora* root, *P. japonicus* root, *P. deniflora* needle corresponding to 232.30, 212.34, 192.65, 138.69 and 137.26 scavenging activities in mg BHT equivalents/g, respectively. The least scavenging ability of <30 mg BHT equivalents/g was observed in the *Z. piperitum* seed and *L. platyphylla* stem extracts. Furthermore, the chloroform extracts exhibited significant ABTS radical scavenging activity (*P<0.05*) in the following five plants and ordered as *S. baicalensis* root, *R. coreanus* fruit, *P. lactiflora* root, *M. bombycis* fruit, and *B. junceae* seed with scavenging activites of 181.84, 124.32, 117.96, 103.78, and 98.57 mg BHT equivalents/g, respectively. However in this study, the *C. sinica* leaf, *C. officinalis* fruit, *L. platyphylla* stem, *M. stenopetala* leaf, and *Z. piperitum* seed chloroform extracts did not show ABTS radical scavenging activity. The five noticeably (*P<0.05*) potent extracts in ABTS radical scavenging capacity from water extracts were as follows *R. coreanus* fruit and *M. piperisens* leaf, *P. deniflora* needle, *M. bombycis* fruit, *L. sativum* seed, and *S. baicalensis* root with the scavenging values of 228.61, 219.07, 185.82, 179.20, 155.44, and 136.93 mg BHT equivalents/g, respectively, and 44.30 mg BHT equivalents/g, respectively, and *P. lactiflora* root, *L. platyphylla* stem, and *C. officinalis* fruit showed no scavenging activity for ABTS radical.

**FRAP antioxidant activity of explored plants**

The FRAP assay is a simple and cost effective technique for determining the total antioxidant activity of samples. After quantifying the change in absorbance at 600 nm and comparing it to the standard, the antioxidant capacity of a given sample can be determined (Halvorsen et al., 2002). The FRAP assay determines whether an extract can donate an electron to Fe(III). The higher the FRAP value, the more potent the antioxidant activity of the sample. Dennig et al. (1999) demonstrated that FRAP can be used to determine the antioxidant status of individuals undergoing hyperbaric oxygen therapy. Table 5 summarizes the FRAP (mg QE/g) antioxidant activity of various solvent extracts of functional plants used in this study. Four of the solvents used in extraction caused a significant (*P<0.05*) variation in FRAP in eight of the 18

---

**Table 4. ABTS radical scavenging activity of various plant solvent extracts (unit: mg BHT equivalents/g)**

| Explored plant | Methanol | Ethanol | Chloroform | Water | SEM |
|----------------|----------|---------|------------|-------|-----|
| Brassica juncea seed | 84.34 | 40.88 | 98.57 | 96.09 | 4.38 |
| Caragana sinica leaf | 95.08 | 110.78 | ND | 37.54 | 3.75 |
| Cornus officinalis fruit | 73.45 | 79.54 | ND | ND | 2.71 |
| Cudrania tricuspidata fruit | 213.87 | 56.25 | 28.46 | 48.76 | 3.25 |
| Lepidium sativum seed | 163.62 | 118.57 | 38.52 | 146.35 | 4.43 |
| Liriope platyphylla stem | 5.96 | 7.53 | ND | ND | 0.76 |
| Lonicer a japonica leaf | 96.45 | 122.79 | 55.92 | 50.17 | 2.37 |
| Mentha piperisens leaf | 129.02 | 134.62 | 33.11 | 219.07 | 7.24 |
| Morina stenopetala leaf | 87.47 | 91.45 | ND | 85.20 | 5.20 |
| Morus bombycis fruit | 182.65 | 129.94 | 103.78 | 155.44 | 10.23 |
| Paeonia lactiflora root | 233.49 | 192.65 | 117.96 | ND | 7.30 |
| Petasites japonicus root | 155.84 | 138.69 | 3.45 | 185.82 | 4.55 |
| Pinus deniflora needle | 195.45 | 137.26 | 64.55 | 179.20 | 4.45 |
| Poncirus trifoliat a fruit | 50.93 | 56.82 | 33.10 | 44.30 | 3.74 |
| Rubus coreanus fruit | 239.46 | 232.30 | 124.32 | 228.61 | 13.85 |
| Scutellaria baicalensis root | 119.91 | 212.34 | 181.84 | 136.93 | 8.43 |
| Taraxacum coreanum flower | 55.04 | 55.18 | 1.61 | 70.07 | 3.89 |
| Zanthoxylum piperitum seed | 66.02 | 23.85 | ND | 67.18 | 2.82 |
| SEM | 6.20 | 6.81 | 3.63 | 6.92 | |

Means in a row (different solvent extracts of the same target plant) followed by uppercase letters (A-D) are significantly different (*P<0.05*).

Means in a column (the same solvent extracts of different target plants) followed by lowercase letters (a-m) are significantly different (*P<0.05*).

ABTS, 2,2’-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid); BHT, butylated hydroxytoluene; SEM, mean standard error (n=3); ND, not detected.
plant materials examined.

Subsequently, we considered the FRAP between various solvent extracts of each plant studied. The methanolic extracts of *C. tricuspidata* fruit, *P. lactiflora* root, and *P. deniflora* needle, ethanolic extract of *R. coreanus* fruit, and water extract of *M. piperascens* leaf had higher FRAPs 

| Explored plant | Various solvent extract | SEM |
|----------------|-------------------------|-----|
|                | Methanol | Ethanol | Chloroform | Water |
| Brassica juncea seed | 21.04<sup>a</sup> | 20.64<sup>ae</sup> | 17.93<sup>b</sup> | 18.56<sup>a</sup> | 2.37 |
| Caragana sinica leaf | 18.85<sup>a</sup> | 19.41<sup>ab</sup> | 18.57<sup>b</sup> | 18.99<sup>ab</sup> | 2.10 |
| Cornus officinalis fruit | 69.20<sup>c</sup> | 71.54<sup>cde</sup> | 68.83<sup>b</sup> | ND | 2.78 |
| Cudrania tricuspidata fruit | 21.79<sup>ef</sup> | 18.73<sup>ade</sup> | 18.54<sup>b</sup> | 19.04<sup>b</sup> | 1.56 |
| Lepidium sativum seed | 23.80<sup>ae</sup> | 23.73<sup>ac</sup> | 18.27<sup>b</sup> | 20.03<sup>b</sup> | 2.13 |
| Liriope platyphylla stem | 68.85<sup>k</sup> | 69.99<sup>k</sup> | 69.92<sup>a</sup> | ND | 3.09 |
| Lonicer a japonica leaf | 4.13<sup>f</sup> | 3.82<sup>f</sup> | 4.08<sup>f</sup> | 3.84<sup>f</sup> | 0.19 |
| Mentha piperascens leaf | 71.87<sup>abc</sup> | 72.97<sup>da</sup> | 69.00<sup>a</sup> | 77.87<sup>ab</sup> | 3.87 |
| Moringa stenopetala leaf | 20.11<sup>cd</sup> | 20.52<sup>de</sup> | 17.86<sup>b</sup> | 19.61<sup>e</sup> | 1.57 |
| Morus bombycis fruit | 21.29<sup>de</sup> | 19.81<sup>bd</sup> | 19.17<sup>b</sup> | 19.88<sup>e</sup> | 2.28 |
| Paeonia lactiflora root | 30.00<sup>ed</sup> | 24.42<sup>bc</sup> | 18.36<sup>c</sup> | ND | 1.68 |
| Petasites japonicus root | 73.71<sup>a</sup> | 74.30<sup>a</sup> | 68.26<sup>b</sup> | 74.71<sup>a</sup> | 3.78 |
| Pinus densiflora needle | 29.98<sup>cd</sup> | 24.80<sup>cd</sup> | 18.98<sup>c</sup> | 25.56<sup>c</sup> | 1.89 |
| Poncirus trifoliata fruit | 18.42<sup>d</sup> | 18.23<sup>d</sup> | 18.10<sup>d</sup> | 18.29<sup>d</sup> | 2.11 |
| Rubus coreanus fruit | 46.32<sup>abc</sup> | 52.05<sup>cd</sup> | 18.40<sup>cd</sup> | 40.44<sup>c</sup> | 2.05 |
| Scutellaria baicalensis root | 21.21<sup>cd</sup> | 19.10<sup>bc</sup> | 17.91<sup>b</sup> | 22.19<sup>bc</sup> | 2.16 |
| Taraxacum coreanum flower | 18.90<sup>d</sup> | 19.43<sup>de</sup> | 18.25<sup>d</sup> | 20.58<sup>d</sup> | 1.78 |
| Zanthoxylum piperitum seed | 69.66<sup>de</sup> | 70.20<sup>e</sup> | 68.59<sup>e</sup> | 67.44<sup>d</sup> | 3.28 |
| SEM | 2.45 | 2.47 | 2.29 | 2.43 |

Means in a row (different solvent extracts of the same target plant) followed by uppercase letters (A-D) are significantly different 

(P<0.05). 

Means in a column (the same solvent extracts of different target plants) followed by lowercase letters (a-g) are significantly different 

(P<0.05).

QE, quercetin equivalents; SEM, standard mean error (n=3); ND, not detected.

In this study, the highest absorbance (>50.00 mg QE/g) of FRAP from methanolic extracts was observed in the following five plant materials: *P. japonicus* root, *M. piperascens* leaf and *Z. piperitum* seed corresponding with 77.87, 74.71, 67.44, 40.44, and 25.56 mg QE/g, re-

Table 5. Ferric reducing antioxidant power of various plant solvent extracts (unit: mg QE/g)
spectively. The water extract of *L. japonica* leaf exhibited the lowest FRAP value of 3.840 mg QE/g, while *P. lactiflora* root, *L. platyphylla* stem, and *C. officinalis* fruit had no FRAP antioxidant activity.

In this study, methanol and ethanol were found to be more effective than chloroform and water in isolating total phenolic content and total flavonoid active compounds and active antioxidant compounds such as ABTS radical scavenging activity and FRAP. The DPPH radical scavenging activity of ethanol and water extracts was notably high. *M. piperascens* leaf extracts exhibited superior total phenolic content (chloroform and water extracts), total flavonoid content (all solvent extracts), DPPH radical scavenging activity (methanol, ethanol, and water extracts), ABTS radical scavenging activity (water extract), and FRAP radical scavenging activity (water extract) (in all solvent extracts). Similarly, *Petasites japonicas* root was another extract with a high total flavonoid content (in all solvent extracts), DPPH and ABTS radical scavenging activity (in methanol, ethanol, and water extracts), and FRAP activity (in methanol, ethanol, and water extracts) (in all solvent extracts). *R. coreanus* fruit with the highest total phenolic content (methanol, ethanol, and water extracts), DPPH and ABTS radical scavenging active (in all solvent extracts), and FRAP in its water extract were the two most effective functional plants. Due to the abundance of antioxidant chemical constituents and the most potent antioxidant activities demonstrated in this study, extracts from *M. piperascens* leaf, *P. japonica* root, and *R. coreanus* fruit are recognized as promising functional plants for meeting the current demand for natural preservatives in the food and pharmaceutical industries.

**REFERENCES**

Ahmed M, Pickova J, Ahmad T, Liaquat M, Farid A, Jahangir M. Oxidation of lipids in foods. Sarhad J Agric. 2016. 32:230-238.

Akwosuah GA, Ismail Z, Norhayati I, Saidkun A. The effects of different extraction solvents of varying polarities on polyphenols of *Orthosiphon stamineus* and evaluation of the free radical-scavenging activity. Food Chem. 2005. 93:311-317.

Anand SP, Sati N. Artificial preservatives and their harmful effects: looking toward nature for safer alternatives. IJPSR. 2013. 4:2496-2501.

Benzie IF, Strain JJ. The ferric reducing ability of plasma (FRAP) as a measure of “antioxidant power”: the FRAP assay. Anal Biochem. 1996. 239:70-76.

Brand-Williams W, Cuvelier ME, Berse C. Use of a free radical method to evaluate antioxidant activity. LWT. 1995. 28:25-30.

Bravo L. Polyphenols: chemistry, dietary sources, metabolism, and nutritional significance. Nutr Rev. 1998. 56:317-333.

Dennog C, Radermacher P, Barnett YA, Spei G. Antioxidant status in humans after exposure to hyperbaric oxygen. Mutat Res. 1999. 428:83-89.

Di Carlo G, Mascalo N, Izzo AA, Capasso F. Flavonoids: old and new aspects of a class of natural therapeutic drugs. Life Sci. 1999. 65:337-353.

Eriksson MC, Doyle MP. The challenges of eliminating or substituting antimicrobial preservatives in foods. Annu Rev Food Sci Technol. 2017. 8:371-390.

Halvorsen BL, Holte K, Myhrstad MC, Barikmo I, Hvittem A, Remberg SF, et al. A systematic screening of total antioxidants in dietary plants. J Nutr. 2002. 132:461-471.

Ilyasov IR, Beloborodov VL, Selivanova IA, Terekhov RP. ABTS/PP decolorization assay of antioxidant capacity reaction pathways. Int J Mol Sci. 2020. 21:1131. https://doi.org/10.3390/ijms21031131

Keller J, Camaré C, Bernis C, Astello-García M, de la Rosa AP, Rossignol M, et al. Antiatherogenic and antitumoral properties of *Opuntia* cladodes: inhibition of low density lipoprotein oxidation by vascular cells, and protection against the cytotoxicity of lipid oxidation product 4-hydroxynonenal in a colorectal cancer cellular model. J Physiol Biochem. 2015. 71:577-587.

Kumari PVK, Akhila S, Rao YS, Devi BR. Alternative to artificial preservatives. Sys Rev Pharm. 2019. 10:99-102.

Li J, Solval KM, Alfaro L, Zhang J, Chotiko A, Delgado JLB, et al. Effect of blueberry extract from blueberry pomeace on the microencapsulated fish oil. J Food Process Preserv. 2015. 39:199-206.

Li XQ, Ji C, Sun YY, Yang ML, Chu XG. Analysis of synthetic antioxidants and preservatives in edible vegetable oil by HPLC/TOF-MS. Food Chem. 2009. 113:692-700.

Meda A, Lamien CE, Romito M, Millogo J, Nacoulma OG. Determination of the total phenolic, flavonoid and proline contents in Burkina Fasan honey, as well as their radical scavenging activity. Food Chem. 2005. 91:571-577.

Mirza SK, Asema UK, Kasim SS. To study the harmful effects of food preservatives on human health. J Med Chem Drug Discov. 2017. 2:610-616.

Montoro P, Braca A, Pizza C, De Tommasi N. Structure-antioxidant activity relationships of flavonoids isolated from different plant species. Food Chem. 2005. 92:349-355.

Nunes XP, Silva FS, Almeida JGRS, de Lima JT, de Araújo Ribeiro LA, Junior Ljq, et al. Biological oxidations and antioxidant activity of natural products. In: Rao V, editor. Phytochemicals as nutraceuticals: Global Approaches to Their Role in Nutrition and Health. IntechOpen, London, UK. 2012. p 1-20. https://www.intechopen.com/chapters/32893

Nychas GJE, Panagou E. Microbiological spoilage of foods and
beverages. In: Kilcast D, Subramaniam P, editors. Food and Beverage Stability and Shelf Life. Woodhead Publishing, Sawston, UK. 2011. p 3-28.

Ozcelik B, Lee JH, Min DB. Effects of light, oxygen, and pH on the absorbance of 2,2-diphenyl-1-picrylhydrazyl. J Food Sci. 2003. 68:487-490.

Pandey RM, Upadhyay SK. Food additive. In: El-Samragy Y, editor. Food Additive. IntechOpen, London, UK. 2012. p 1-30. https://www.intechopen.com/chapters/28906

Petruzzi L, Corbo MR, Sinigaglia M, Bevilacqua A. Microbial spoilage of foods: fundamentals. In: Bevilacqua A, Corbo MR, Sinigaglia M, editors. The Microbiological Quality of Food: Foodborne Spoilers. Woodhead Publishing, Sawston, UK. 2017. p 1-21.

Potter JD. Vegetables, fruit, and cancer. Lancet. 2005. 366:527-530.

Prabhune AM, Jadhav SN, Kadam DA, Nandikar MD, Aparadh VT. Free radical scavenging (DPPH) and ferric reducing ability (FRAP) of some Commelinaceae members. IJBPAS. 2013. 2:1128-1134.

Prior RL, Wu X, Schaich K. Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements. J Agric Food Chem. 2005. 53:4290-4302.

Re R, Pellegretini N, Proteggente A, Pannala A, Yang M, Rice-Evans C. Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Radic Biol Med. 1999. 26:1231-1237.

Saeed F, Afzaal M, Tufail T, Ahmad A. Use of natural antimicrobial agents: a safe preservation approach. In: Var I, Uzunlu S, editors. Active Antimicrobial Food Packaging. IntechOpen, London, UK. 2019. https://www.intechopen.com/chapters/63469

Sharma S. Food preservatives and their harmful effects. Int J Sci Res Publ. 2015. 5:1-2.

Shyur LF, Tsung JH, Chen JH, Chiu CY, Lo CP. Antioxidant properties of extracts from medicinal plants popularly used in Taiwan. Int J Appl Sci Eng. 2005. 3:195-202.

Singleton VL, Rossi JA. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Am J Enol Vitic. 1965. 16:144-158.

Soobrattee MA, Neergheen VS, Luximon-Ramma A, Aruoma OI, Bahorun T. Phenolics as potential antioxidant therapeutic agents: mechanism and actions. Mutat Res. 2005. 579:200-213.