

Extensive screening for herbal extracts with potent antioxidant properties

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This paper summarizes our research for herbal extracts with potent antioxidant activity obtained from a large scale screening based on superoxide radical ($O_2^{\cdot-}$) scavenging activity followed by characterization of antioxidant properties. Firstly, scavenging activity against $O_2^{\cdot-}$ was extensively screened from ethanol extracts of approximately 1000 kinds of herbs by applying an electron spin resonance (ESR)-spin trapping method, and we chose four edible herbal extracts with prominently potent ability to scavenge $O_2^{\cdot-}$. They are the extracts from *Punica granatum* (Peel), *Syzygium aromaticum* (Bud), *Mangifera indica* (Kernel), and *Phyllanthus emblica* (Fruit). These extracts were further examined to determine if they also scavenge hydroxyl radical ($\cdot OH$), by applying the ESR spin-trapping method, and if they have heat resistance as a desirable characteristic feature. Experiments with the Fenton reaction and photolysis of H_2O_2 induced by UV irradiation demonstrated that all four extracts have potent ability to directly scavenge $\cdot OH$. Furthermore, the scavenging activities against $O_2^{\cdot-}$ and $\cdot OH$ of the extracts of *P. granatum* (peel), *M. indica* (kernel) and *P. emblica* (fruit) proved to be heat-resistant.

The results of the review might give useful information when choosing a potent antioxidant as a foodstuff. For instance, the four herbal extracts chosen from extensive screening possess desirable antioxidant properties. In particular, the extracts of the aforementioned three herbs are expected to be suitable for food processing in which thermal devices are used, because of their heat resistance.

Key Words: herbal extracts, scavenging activity, superoxide anions, hydroxyl radicals, antioxidant properties

Superoxide radical ($O_2^{\cdot-}$) is known to be harmful to cellular components and to function as a precursor of other reactive oxygen species (ROS), such as singlet oxygen (1O_2) and hydroxyl radical ($\cdot OH$).⁽¹⁻⁶⁾ A dismutation reaction can result in the formation of hydrogen peroxides (H_2O_2) and O_2 from the reaction of $O_2^{\cdot-}$ with water.⁽⁴⁾ A reactive non radical, H_2O_2 is very important because it can penetrate biological membranes. Although H_2O_2 itself is not very reactive, it can convert into more reactive species such as $\cdot OH$, the most reactive and harmful ROS, by ultraviolet irradiation, Fenton like reactions and the metal ion catalyzed Haber-Weiss reaction.^(5,6) Electron spin resonance (ESR) using the spin trapping agent 5,5-dimethyl-1-pyrroline-*N*-oxide (DMPO) is a technique for the direct detection of unpaired electrons such as $O_2^{\cdot-}$ and $\cdot OH$, both of which are identified by hyperfine coupling constants assigned to the spin adducts such as DMPO-OOH (an adduct from DMPO and $O_2^{\cdot-}$) and DMPO-OH (an adduct from DMPO and $\cdot OH$).⁽⁷⁾

Foodstuffs possess two major functions. That is, the primary function is nutritional feature (life support), and the secondary

function is gustational feature (taste, flavor, and texture). Recently, antioxidant potency has been received much attention as one of the tertiary function of foodstuffs. For instance, human studies with de-alcoholized red but white wine showed short-term cardiovascular benefits, and the specific components of the de-alcoholized wine that are active on cardiovascular endpoints are the polyphenols found in red wine, especially resveratrol.⁽⁸⁻¹³⁾ In addition to its potent antioxidant properties,^(14,15) it has recently been reported that resveratrol mimics the anti-ageing effects of calorie restriction in lower organisms, and ameliorates insulin resistance, increases mitochondrial content, and prolongs survival in mice fed a high-fat diet.⁽¹⁶⁾ Based on these backgrounds, we conducted a large scale screening to search for edible herbal extracts with potent antioxidant activity.^(17,18) In this review, we summarize our research for herbal extracts with potent antioxidant activity obtained from a large scale screening based on $O_2^{\cdot-}$ scavenging activity followed by characterization of antioxidant properties.

A Large Scale Screening for Herbal Extracts with Potent $O_2^{\cdot-}$ Scavenging Activity

More than a thousand of herbal ethanol extracts were prepared as shown in Table 1. The assay used in this study was essentially identical to that described in our previous papers.⁽¹⁹⁻²¹⁾ In brief, 50 μ l of 2 mM hypoxanthine (HPX), 30 μ l of dimethyl sulfoxide (DMSO), 50 μ l of sample dissolved in DMSO, 20 μ l of 4.5 M DMPO, and 50 μ l of 0.4 U/ml xanthine oxidase (XOD) were placed in a test tube and mixed. In the primary screening, all of the herbal extracts were served at a fixed concentration of 25 μ g/ml in the reaction mixture. The mixture was transferred to an ESR spectrometry cell, and the DMPO-OOH spin adduct was quantified 100 s after the addition of XOD. When a spin trapping agent, DMPO, was added to a solution of the HPX-XOD reaction system, an ESR signal with the hyperfine coupling constants of $a_N = 1.37$ mT, $a_{H\beta} = 1.10$ mT, $a_{H\gamma} = 0.12$ mT was observed. This signal was assigned to the spin adduct, DMPO-OOH, by the hyperfine coupling constants.⁽⁷⁾ The reduction of the signal intensity of DMPO-OOH is likely reflected by the ability to scavenge $O_2^{\cdot-}$. Polyphenol contents of some herbal extracts were determined by Folin-Denis method,⁽⁸⁾ and results were expressed as garlic acid equivalency.

Table 1 shows a list of all herbs tested and herbs that showed 80% or more reduction of signal intensity of DMPO-OOH measured by ESR-spin trapping method at a fixed concentration of

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Table 1. List of herbs. Bold letters show herbs that showed 80% or more reduction of signal intensity of DMPO-OOH measured by ESR-spin trapping method. Shaded columns indicate finally selected four herbs.

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
A-001	Rheum palmatum (Rhizome)	A-026	<i>Plantago asiatica</i> (Aerial part)	A-051	<i>Phellodendron amurense</i> (Bark)	A-076	<i>Periploca sepium</i> (Root)
A-002	<i>Sophora flavescens</i> (Root)	A-027	<i>Stephania tetrandra</i> (Stem)	A-052	<i>Polygonum multiflorum</i> (Stem)	A-077	<i>Selaginella tamariscina</i> (Herb)
A-003	<i>Cynanthum auriculatum</i> (Root)	A-028	<i>Isatis indigotica</i> (Root)	A-053	<i>Euphorbia helioscopia</i> (Herb)	A-078	<i>Taraxacum mongolicum</i> (Aerial part)
A-004	<i>Cyathula officinalis</i> (Root)	A-029	<i>Clematis chinensis</i> (Underground part)	A-054	<i>Chrysanthemum indicum</i> (Flower)	A-079	<i>Phragmites communis</i> (Rhizome)
A-005	<i>Gentiana scabra</i> (Root)	A-030	<i>Curcuma longa</i> (Root)	A-055	<i>Zea mays</i> (Style and stigma)	A-080	<i>Speranskia tuberculata</i> (Herb)
A-006	Polygonum cuspidatum (Rhizome)	A-031	<i>Piper kadsura</i> (Stem)	A-056	<i>Salvia miltiorrhiza</i> (Root)	A-081	<i>Pyrrosia lingua</i> (Leaf)
A-007	<i>Lophatherum gracile</i> (Aerial part)	A-032	<i>Equisetum hyemale</i> (Aerial part)	A-057	<i>Pseudolarx kaempferi</i> (Bark)	A-082	<i>Aristolochia manshuriensis</i> (Stem)
A-008	<i>Trichosanthes kirilowee</i> (Root)	A-033	<i>Prunus persica</i> (Seed)	A-058	Punica granatum (Peel)	A-083	<i>Fortunella margarita</i> (Leaf)
A-009	Paeoniae suffruticosa (Root bark)	A-034	<i>Ligusticum chuanxiong</i> (Rhizome)	A-059	Caesalpinia sappan (Wood)	A-084	<i>Glycyrrhiza uralensis</i> (Root and stolon)
A-010	<i>Cassia angustifolia</i> (Leaf)	A-035	<i>Scrophularia ningpoensis</i> (Root)	A-060	<i>Viscum album</i> var. <i>coloratum</i> (Leaf)	A-085	<i>Polygonatum officinale</i> (Rhizome)
A-011	<i>Scutellaria barbata</i> (Aerial part)	A-036	<i>Achyranthes bidentata</i> (Root)	A-061	<i>Schizonepeta tenuifolia</i> (Spike)	A-086	<i>Rehmannia glutinosa</i> var. <i>hueichingensis</i> (Root)
A-012	<i>Cirsium japonicum</i> (Aerial part)	A-037	<i>Aristolochia contorta</i> (Root)	A-062	<i>Drynaria fortunei</i> (Rhizome)	A-087	<i>Leonurus sibiricus</i> (Stem and leaf)
A-013	<i>Prunella vulgaris</i> (Spike)	A-038	<i>Ophiopogon japonicus</i> (Root)	A-063	<i>Areca catechu</i> (Peel)	A-088	<i>Dioscorea bulbifera</i> (Tuber)
A-014	Not identified	A-039	<i>Glycine max</i> (Seed coat)	A-064	<i>Quisqualis indica</i> (Fruit)	A-089	<i>Pyrola rotundifolia</i> (Herb)
A-015	<i>Areca catechu</i> (Seed)	A-040	<i>Angelica pubescens</i> (Underground part)	A-065	<i>Citrus aurantium</i> (Fruit)	A-090	<i>Siegesbeckia orientalis</i> (Herb)
A-016	<i>Dictamnus dasycarpus</i> (Root bark)	A-041	<i>Forsythia suspensa</i> (Fruit)	A-066	<i>Cimicifuga simplex</i> (Rhizome)	A-091	<i>Thuja orientalis</i> (Kernel)
A-017	Not identified	A-042	<i>Cinamomum cassia</i> (Bark)	A-067	<i>Loniceria japonica</i> (Stem and leaf)	A-092	<i>Anemarrhena asphodeloides</i> (Rhizome)
A-018	<i>Benincasa hispida</i> (Peel)	A-043	<i>Atractylodes lancea</i> (Rhizome)	A-068	<i>Leonurus sibiricus</i> (Fruit)	A-093	<i>Ephedra sinica</i> (Root)
A-019	<i>Sophora tonkinensis</i> (Root)	A-044	<i>Erythrina variegata</i> (Bark)	A-069	Dalbergia odorifera (Heart wood of root)	A-094	<i>Chaenomeles lagenaria</i> (Fruit)
A-020	<i>Sparganium stoloniferum</i> (Rhizome)	A-045	<i>Rhaponticum uniflorum</i> (Root)	A-070	<i>Aristolochia mollissima</i> (Stem and leaf)	A-095	<i>Raphanus sativus</i> (Leaf)
A-021	<i>Stemona japonica</i> (Root)	A-046	<i>Aristolochia contorta</i> (Stem and leaf)	A-071	<i>Portulaca oleracea</i> (Herb)	A-096	<i>Gardenia jasminoides</i> (Fruit)
A-022	<i>Curcuma longa</i> (Rhizome)	A-047	<i>Sinomenium acutum</i> (Rhizome and stem)	A-072	<i>Capsella Bursa-pastoris</i> (Herb)	A-097	<i>Morus alba</i> (Immature branch)
A-023	<i>Trichosanthes kirilowii</i> (Fruit)	A-048	<i>Eclipta alba</i> (Herb)	A-073	<i>Hypericum japonicum</i> (Herb)	A-098	<i>Euonymus alatus</i> (Branch)
A-024	<i>Poria cocos</i> (Sclerotium)	A-049	Ephedra sinica (Aerial part)	A-074	<i>Mentha arvensis</i> var. <i>piperascens</i> (Stem and leaf)	A-099	<i>Eucommia ulmoides</i> (Bark)
A-025	<i>Aster tataricus</i> (Underground part)	A-050	<i>Dryopteris crassirhizoma</i> (Rhizome)	A-075	<i>Eclipta alba</i> (Herb)	A-100	<i>Agrimonia pilosa</i> (Aerial part)

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
B-001	<i>Boehmeria nivea</i> (Root)	B-026	<i>Angelica sinensis</i> (Root)	B-051	<i>Ligusticum sinense</i> (Aerial part)	B-076	<i>Atropa belladonna</i> (Stem)
B-002	<i>Perilla frutescens</i> var. <i>acuta</i> (Leaf)	B-027	<i>Scutellaria baicalensis</i> (Root)	B-052	<i>Fagopyrum cymosum</i> (Root)	B-077	<i>Ricinus communis</i> (Seed)
B-003	<i>Sophora japonica</i> (Bud)	B-028	<i>Lilium brownii</i> var. <i>colchesteri</i> (Bulb)	B-053	<i>Peucedanum praeruptorum</i> (Root)	B-078	<i>Momordica grosvenori</i> (Fruit)
B-004	<i>Prunus armeniaca</i> (Kernel)	B-029	<i>Homalomena occulta</i> (Rhizome)	B-054	<i>Saussurea lappa</i> (Root)	B-079	<i>Nelumbo nucifera</i> (Seed)
B-005	<i>Sargassum fulvellum</i> (Herb)	B-030	<i>Angelica dahurica</i> (Root)	B-055	<i>Dioscorea hypoglauca</i> (Rhizome)	B-080	<i>Convallaria keiskei</i> (Stem and leaf)
B-006	<i>Lycopus lucidus</i> (Stem and leaf)	B-031	<i>Cynanchum atratum</i> (Root)	B-056	<i>Dipsacus asper</i> (Root)	B-081	<i>Ranunculus japonicus</i> (Stem and leaf)
B-007	<i>Viola yedoensis</i> (Herb)	B-032	<i>Patrinia heterophylla</i> (Root)	B-057	<i>Artemisia capillaris</i> (Immature aerial part)	B-082	<i>Opuntia dillenii</i> (Stem)
B-008	<i>Salvia chinensis</i> (Herb)	B-033	<i>Acorus gramineus</i> (Rhizome)	B-058	<i>Cirsium tanakae</i> (Root)	B-083	<i>Eriocaulon buergerianum</i> (Flower)
B-009	<i>Houttuynia cordata</i> (Aerial part)	B-034	<i>Cynanchum stauntoni</i> (Rhizome)	B-059	<i>Imperata cylindrica</i> (Rhizome)	B-084	<i>Cuscuta chinensis</i> (Seed)
B-010	<i>Centella asiatica</i> (Herb)	B-035	<i>Cinamomum cassia</i> (Immature branch)	B-060	<i>Mosla chinensis</i> (Aerial part)	B-085	<i>Phytolacca esculenta</i> (Root)
B-011	<i>Bupleurum falcatum</i> (Immature aerial part)	B-036	<i>Lycopodium clavatum</i> (Herb)	B-061	<i>Saegentodoxa cuneata</i> (Stem)	B-086	<i>Oryza sativa</i> (Germinated fruit)
B-012	<i>Isatis indigotica</i> (Stem and leaf)	B-037	<i>Smilax glabra</i> (Rhizome)	B-062	<i>Picrorrhiza kurroa</i> (Rhizome)	B-087	<i>Campsis grandiflora</i> (Flower)
B-013	<i>Morus alba</i> (Leaf)	B-038	<i>Paeonia lactiflora</i> (Root without periderm)	B-063	<i>Pueraria lobata</i> (Root)	B-088	<i>Gleditsia sinensis</i> (Fruit)
B-014	<i>Artemisia apiacea</i> (Herb)	B-039	<i>Prunus mume</i> (Immature fruit)	B-064	<i>Allium macrostemon</i> (Bulb)	B-089	<i>Cinamomum cassia</i> (Bark)
B-015	<i>Corydalis tutschaninovi</i> (Tuber)	B-040	<i>Magnolia officinalis</i> (Bark)	B-065	<i>Codonopsis pilosula</i> (Root)	B-090	<i>Strychnos nux-vomica</i> (Seed)
B-016	<i>Curcuma zedoaria</i> (Rhizome)	B-041	Bistorta vulgaris (Rhizome)	B-066	<i>Luffa cylindrica</i> (Fiber of fruit)	B-091	<i>Aristolochia contorta</i> (Fruit)
B-017	<i>Lindera strychnifolia</i> (Root)	B-042	<i>Oryza sativa</i> (Root)	B-067	<i>Eriobotrya japonica</i> (Leaf)	B-092	Not identified
B-018	<i>Cibotium barometz</i> (Rhizome)	B-043	<i>Illicium difengpi</i> (Underground part)	B-068	<i>Osmanthus fragrans</i> (Flower)	B-093	<i>Amomum kravanh</i> (Fruit)
B-019	<i>Desmodium styracifolium</i> (Herb)	B-044	<i>Cynomorium songaricum</i> (Stem)	B-069	<i>Euphorbia kansui</i> (Root)	B-094	<i>Evdia rutaecarpa</i> (Immature fruit)
B-020	<i>Zingiber officinale</i> (Rhizome)	B-045	<i>Paeonia veitchii</i> (Root)	B-070	Acacia catechu (Wood)	B-095	<i>Sedum sarmentosum</i> (Herb)
B-021	<i>Epimedium sagittatum</i> (Stem and leaf)	B-046	<i>Dioscorea futschauensis</i> (Rhizome)	B-071	Rosa rugosa var. <i>pleva</i> (Bud)	B-096	<i>Adenophora stricta</i> (Root)
B-022	<i>Atractylodes ovata</i> (Rhizome)	B-047	<i>Dianthus superbus</i> (Aerial part with flower)	B-072	<i>Eupatorium lindleyanum</i> var. <i>trifoliolatum</i> (Aerial part)	B-097	<i>Sterculia scaphigera</i> (Seed)
B-023	<i>Astragalus membranaceus</i> (Root)	B-048	<i>Coix lachryma-jobi</i> var. <i>ma-yuen</i> (Seed)	B-073	<i>Firmiana simplex</i> (Seed)	B-098	<i>Aconitum carmichaeli</i> (Root)
B-024	<i>Pulsatilla chinensis</i> (Root)	B-049	<i>Perilla frutescens</i> var. <i>acuta</i> (Underground part)	B-074	<i>Artemisia argyi</i> (Leaf)	B-099	<i>Arisaema consanguineum</i> (Tuber)
B-025	<i>Inula japonica</i> (Flower)	B-050	<i>Trachelospermum jasminoides</i> (Stem and leaf)	B-075	<i>Daphne genkwa</i> (Bud)	B-100	<i>Nelumbo nucifera</i> (Leaf)

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
C-001	<i>Perilla frutescens</i> (Seed)	C-026	<i>Glycine max</i> (Fermented seed)	C-051	<i>Morus alba</i> (Fruit)	C-076	<i>Curculigo orchioideis</i> (Rhizome)
C-002	<i>Illicium verum</i> (Fruit)	C-027	<i>Glehnia littoralis</i> (Root)	C-052	<i>Citrus medica</i> var. <i>sarcodactylus</i> (Fruit)	C-077	<i>Impatiens balsamina</i> (Seed)
C-003	<i>Loniceria japonica</i> (Stem and leaf)	C-028	<i>Acanthopanax gracilistylus</i> (Root bark)	C-053	<i>Cistanche deserticola</i> (Stem)	C-078	<i>Pteris multifida</i> (Herb)
C-004	<i>Dendrobium nobile</i> (Stem)	C-029	<i>Uncaria rhynchophylla</i> (Hook with stem)	C-054	<i>Phyllostachys nigra</i> var. <i>henonis</i> (Stem without bark)	C-079	<i>Physalis alkekengi</i> var. <i>franchetii</i> (Herb)
C-005	<i>Vaccaria pyramidata</i> (Seed)	C-030	<i>Thuja orientalis</i> (Branch with leaf)	C-055	<i>Astragalus complanatus</i> (Seed)	C-080	<i>Nelumbo nucifera</i> (Germ)
C-006	<i>Xanthium strumarium</i> (Fruit)	C-031	<i>Apocynum venetum</i> (Herb)	C-056	<i>Notopterygium incisum</i> (Root)	C-081	<i>Saussurea japonica</i> (Herb)
C-007	<i>Torreya grandis</i> (Seed)	C-032	<i>Menispermum dauricum</i> (Root)	C-057	Sanguisorba officinalis (Underground part)	C-082	<i>Semiaquilegia adoxoides</i> (Root)
C-008	<i>Pinellia ternata</i> (Rhizome)	C-033	<i>Psoralea corylifolia</i> (Seed)	C-058	<i>Paris polyphylla</i> var. <i>chinensis</i> (Rhizome)	C-083	<i>Photinia serrulata</i> (Leaf)
C-009	<i>Schizandra chinensis</i> (Fruit)	C-034	<i>Ligustrum lucidum</i> (Fruit)	C-059	<i>Solanum nigrum</i> (Herb)	C-084	<i>Allium sativum</i> (Bulb)
C-010	<i>Datura metel</i> (Flower)	C-035	<i>Rubia cordifolia</i> (Underground part)	C-060	<i>Toona sinensis</i> (Bark)	C-085	<i>Alpinia oxyphylla</i> (Fruit)
C-011	<i>Cnidium monnieri</i> (Fruit)	C-036	<i>Hordeum vulgare</i> (Germinated fruit)	C-061	<i>Catharanthus roseus</i> (Herb)	C-086	<i>Ampelopsis japonica</i> (Root)
C-012	<i>Cannabis sativa</i> (Kernel)	C-037	Syzygium aromaticum (Bud)	C-062	<i>Dioscorea japonica</i> (Rhizome)	C-087	<i>Dichroa febrifuga</i> (Root)
C-013	<i>Licium chinense</i> (Fruit)	C-038	<i>Zanthoxylum bungeanum</i> (Peel)	C-063	<i>Acanthopanax senticosus</i> (Root and rhizome)	C-088	<i>Gynostemma pentaphyllum</i> (Rhizome)
C-014	<i>Fraxinus rhynchophylla</i> (Bark)	C-039	<i>Cornus officinalis</i> (Fruit)	C-064	<i>Zanthoxylum nitidum</i> (Root, root bark and stem bark)	C-089	<i>Alpinia galanga</i> (Fruit)

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
C-015	<i>Melia azedarach</i> (Bark/root bark)	C-040	<i>Ginkgo biloba</i> (Leaf)	C-065	<i>Ilex pubescens</i> (Root)	C-090	<i>Cynanchum paniculatum</i> (Herb)
C-016	<i>Typhonium giganteum</i> (Tuber)	C-041	<i>Duchesnea indica</i> (Herb)	C-066	<i>Polygala tenuifolia</i> (Root and root bark)	C-091	<i>Solanum tuberosum</i> (Root)
C-017	<i>Rubus chingii</i> (Fruit)	C-042	<i>Lobelia chinensis</i> (Herb)	C-067	<i>Crataegus pinnatifida</i> var. <i>major</i> (Fruit)	C-092	<i>Magnolia officinalis</i> (Bud)
C-018	<i>Tussilago farfara</i> (Bud)	C-043	<i>Morinda officinalis</i> (Root)	C-068	<i>Polyporus umbellatus</i> (Sclerotium)	C-093	<i>Sophora japonica</i> (Fruit)
C-019	<i>Liquidambar formosana</i> (Fruit)	C-044	<i>Clematis armandi</i> (Stem)	C-069	<i>Garcinia morella</i> (Resin)	C-094	<i>Zizania caduciflora</i> (Sclerotium)
C-020	<i>Asiasarum heterotropoides</i> (Root and rhizome)	C-045	<i>Terminalia chebula</i> (Fruit)	C-070	<i>Juncus effusus</i> var. <i>decipiens</i> (Herb)	C-095	<i>Ranunculus ternatus</i> (Root)
C-021	<i>Melia toosendan</i> (Fruit)	C-046	<i>Citrus tangerina</i> (Fruit)	C-071	<i>Tinospora capillipes</i> (Root)	C-096	<i>Trigonella foenum-graecum</i> (Seed)
C-022	<i>Amomum longiligulave</i> (Seed)	C-047	<i>Morus alba</i> (Root bark without cork layer)	C-072	<i>Cucurbita moschata</i> (Fruit)	C-097	<i>Magnolia liliflora</i> (Bud)
C-023	<i>Prunus japonica</i> (Seed)	C-048	<i>Canavalia gladiata</i> (Seed)	C-073	<i>Chrysanthemum morifolium</i> (Flower)	C-098	<i>Bletilla striata</i> (Root)
C-024	<i>Aristolochia kaempferi</i> (Root)	C-049	<i>Lysionotus pauciflora</i> (Herb)	C-074	<i>Nardostachys chinensis</i> (Rhizome)	C-099	<i>Tribulus terrestris</i> (Fruit)
C-025	<i>Arctium lappa</i> (Seed)	C-050	<i>Andropogon paniculata</i> (Herb)	C-075	<i>Carthamus tinctorius</i> (Flower)	C-100	<i>Daucus carota</i> (Herb)

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
D-001	<i>Myristica fragrans</i> (Seed without coat)	D-026	<i>Callicarpa japonica</i> (Leaf)	D-051	<i>Luffa cylindrica</i> (Dry fruit)	D-076	<i>Prunus persica</i> (Leaf)
D-002	<i>Dolichos lablab</i> (Seed)	D-027	<i>Patrinia scabiosaefolia</i> (Herb)	D-052	<i>Broussonetia papyrifera</i> (Branch)	D-077	<i>Malus pumila</i> (Fruit)
D-003	<i>Michelia alba</i> (Flower)	D-028	<i>Pinus tabulaeformis</i> (Knot)	D-053	<i>Erodium stephanianum</i> (Herb with fruit)	D-078	<i>Capsicum frutescens</i> (Fruit)
D-004	<i>Buddleia officinalis</i> (Bud)	D-029	<i>Solanum lyratum</i> (Herb)	D-054	<i>Cucumis melo</i> var. <i>flexuosus</i> (Fruit)	D-079	<i>Citrus aurantium</i> (Immature fruit)
D-005	<i>Brucea javanica</i> (Fruit)	D-030	<i>Amomum villosum</i> (Peel)	D-055	<i>Oryza sativa</i> (Unpolished rice)	D-080	<i>Eupatorium fortunei</i> (Aerial part)
D-006	<i>Broussonetia papyrifera</i> (Fruit)	D-031	<i>Momordica charantia</i> (Fruit)	D-056	<i>Raphanus sativus</i> (Root)	D-081	<i>Kochia scoparia</i> (Fruit)
D-007	<i>Citrus aurantium</i> var. <i>daidai</i> (Bud)	D-032	<i>Kochia scoparia</i> (Immature aerial part)	D-057	<i>Brassica alba</i> (Seed)	D-082	<i>Citrullus vulgaris</i> (Seed)
D-008	<i>Vitex rotundifolia</i> (Fruit)	D-033	<i>Ficus carica</i> (Leaf)	D-058	<i>Salix babylonica</i> (Branch)	D-083	<i>Rosa chinensis</i> (Leaf)
D-009	<i>Citrus tangerina</i> (Immature peel)	D-034	<i>Foeniculum vulgare</i> (Fruit)	D-059	<i>Polygala japonica</i> (Herb)	D-084	<i>Abutilon avicennae</i> (Seed)
D-010	<i>Kaempferia galanga</i> (Rhizome)	D-035	<i>Chenopodium serotinum</i> (Stem and leaf)	D-060	<i>Litsea cubeba</i> (Immature fruit)	D-085	<i>Typha angustifolia</i> (Pollen)
D-011	<i>Zea mays</i> (Seed)	D-036	<i>Clerodendron trichotomum</i> (Immature branch and leaf)	D-061	<i>Prunus armeniaca</i> (Kernel)	D-086	<i>Trachycarpus fortunei</i> (Leaf sheath)
D-012	<i>Cucumis sativus</i> (Fruit)	D-037	<i>Mahonia bealei</i> (Leaf)	D-062	<i>Xanthium strumarium</i> (Aerial part)	D-087	<i>Polygonum hydropiper</i> (Flower and leaf)
D-013	<i>Ilex cornuta</i> (Leaf)	D-038	<i>Plantago asiatica</i> (Seed)	D-063	<i>Citrus medica</i> (Fruit)	D-088	<i>Diospyros kaki</i> (Leaf)
D-014	<i>Oroxylum indicum</i> (Seed)	D-039	<i>Cyperus rotundus</i> (Rhizome)	D-064	<i>Vigna radiata</i> (Seed)	D-089	<i>Lygodium japonicum</i> (Ripe spore)
D-015	<i>Zizyphus jujub</i> var. <i>inermis</i> (Fruit)	D-040	<i>Vitis vinifera</i> (Aerial part)	D-065	<i>Lonicera japonica</i> (Bud)	D-090	<i>Polygonum orientale</i> (Fruit)
D-016	<i>Sorghum vulgare</i> (Kernel)	D-041	<i>Luffa cylindrica</i> (Leaf)	D-066	<i>Purpurea persica</i> (Immature branch)	D-091	<i>Albizia julibrissin</i> (Bark)
D-017	<i>Prunus persica</i> (Seed)	D-042	<i>Rumex japonicus</i> (Leaf)	D-067	<i>Litchi chinensis</i> (Epicarp)	D-092	<i>Polygonatum sibiricum</i> (Rhizome)
D-018	<i>Trichosanthes kirilowii</i> (Peel)	D-043	<i>Cayratia japonica</i> (Aerial part)	D-068	<i>Rosa laevigata</i> (Fruit)	D-093	<i>Saposhnikovia divaricata</i> (Root and rhizome)
D-019	<i>Stellaria dichotoma</i> var. <i>lanceolata</i> (Root)	D-044	<i>Citrullus vulgaris</i> (Root and leaf)	D-069	<i>Sonchus oleraceus</i> (Herb)	D-094	<i>Celosia argentea</i> (Seed)
D-020	<i>Oryza sativa</i> (Germinated fruit)	D-045	<i>Broussonetia papyrifera</i> (Leaf)	D-070	<i>Cucumis sativus</i> (Leaf)	D-095	<i>Celosia cristata</i> (Fruit)
D-021	<i>Citrullus vulgaris</i> (Peel)	D-046	<i>Gleditsia sinensis</i> (Fruit)	D-071	<i>Ipomoea aquatica</i> (Stem and leaf)	D-096	<i>Euphorbia humifusa</i> (Herb)
D-022	<i>Kalimeris indica</i> (Herb)	D-047	<i>Litchi chinensis</i> (Seed)	D-072	<i>Momordica charantia</i> (Seed)	D-097	<i>Wisteria sinensis</i> (Stem and leaf)
D-023	<i>Toona sinensis</i> (Leaf)	D-048	<i>Solanum melongena</i> (Fruit)	D-073	<i>Piper longum</i> (Immature spike)	D-098	<i>Euryale ferox</i> (Seed)
D-024	<i>Brassica aleracea</i> var. <i>capitata</i> (Leaf)	D-049	<i>Canarium album</i> (Fruit)	D-074	<i>Cucumis melo</i> (Calyx)	D-099	<i>Spiridela polyrhiza</i> (Herb)
D-025	<i>Luffa cylindrica</i> (Peel)	D-050	<i>Salix babylonica</i> (Leaf)	D-075	<i>Phaseolus calcaratus</i> (Seed)	D-100	<i>Cassia obtusifolia</i> (Seed)

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
E-001	<i>Albizia julibrissin</i> (Flower)	E-026	<i>Benincasa hispida</i> (Fruit)	E-051	<i>Solanum melongena</i> (Leaf)	E-076	<i>Allium tuberosum</i> (Leaf and peduncle)
E-002	<i>Ziziphus jujuba</i> (Seed)	E-027	<i>Asparagus officinalis</i> (Stem)	E-052	<i>Firmiana simplex</i> (Bark without cork)	E-077	<i>Sophora japonica</i> (Immature branch)
E-003	<i>Raphanus sativus</i> (Seed)	E-028	<i>Parthenocissus tricuspidata</i> (Root and stem)	E-053	<i>Allium fistulosum</i> (Leaf)	E-078	<i>Impatiens balsamina</i> (Aerial part)
E-004	<i>Allium tuberosum</i> (Seed)	E-029	<i>Brassica pekinensis</i> (Leaf)	E-054	<i>Coriandrum sativum</i> (Herb)	E-079	<i>Euphorbia longan</i> (Ail)
E-005	<i>Ilex cornuta</i> (Leaf)	E-030	<i>Lepidium virginicum</i> (Leaf)	E-055	<i>Verbena officinalis</i> (Aerial part)	E-080	<i>Allium sativum</i> (Flower)
E-006	<i>Alisma plantago-aquatica</i> var. <i>orientale</i> (Tuber)	E-031	<i>Saxifraga stolonifera</i> (Herb)	E-056	<i>Rosa chinensis</i> (Flower)	E-081	<i>Cucurbita moschata</i> (Stem)
E-007	<i>Abutilon theophrasti</i> (Stem and leaf)	E-032	<i>Nelumbo nucifera</i> (Flower receptacle)	E-057	<i>Ipomoea batatas</i> (Root)	E-082	<i>Catalpa ovata</i> (Fruit)
E-008	<i>Datura metel</i> (Leaf)	E-033	<i>Akebia quinata</i> (Fruit)	E-058	<i>Trachycarpus wagnerianus</i> (Leaf)	E-083	<i>Citrus grandis</i> (Fruit without epicarp and mesocarp)
E-009	<i>Lithospermum erythrorhizon</i> (Root)	E-034	<i>Cucumis melo</i> (Fruit)	E-059	<i>Trapa bispinosa</i> (Sarcocarp)	E-084	<i>Lagenaria siceraria</i> var. <i>clavata</i> (Fruit)
E-010	<i>Cucumis melo</i> (Stem and leaf)	E-035	<i>Musa paradisiaca</i> var. <i>sapientum</i> (Fruit)	E-060	<i>Castanea mollissima</i> (Kernel)	E-085	<i>Amaranthus mangostanus</i> (Leaf)
E-011	<i>Centipda minima</i> (Herb with flower)	E-036	<i>Benincasa hispida</i> (Seed)	E-061	<i>Trachycarpus fortunei</i> (Wood)	E-086	<i>Cucumis melo</i> (Root)
E-012	<i>Cucumis melo</i> (Stem)	E-037	<i>Aesculus chinensis</i> (Fruit)	E-062	<i>Trapa bispinosa</i> (Peel)	E-087	<i>Capsicum frutescens</i> (Root)
E-013	<i>Campsis grandiflora</i> (Stem and leaf)	E-038	<i>Sophora japonica</i> (Leaf)	E-063	<i>Nelumbo nucifera</i> (Petiole and peduncle)	E-088	<i>Nelumbo nucifera</i> (Rhizome)
E-014	<i>Solanum melongena</i> (Stem and root)	E-039	<i>Citrus tangerina</i> (Exocarp of peel)	E-064	<i>Aloe vera</i> (Stem and leaf)	E-089	<i>Vigna sinensis</i> (Seed)
E-015	<i>Abrus fruticulosus</i> (Herb)	E-040	<i>Alpinia katsumadai</i> (Seed)	E-065	<i>Pyrus bretschneideri</i> (Fruit)	E-090	<i>Actinidia chinensis</i> (Fruit)
E-016	<i>Polygonum aviculare</i> (Herb)	E-041	<i>Musa paradisiaca</i> var. <i>sapientum</i> (Peel)	E-066	<i>Chrysanthemum morifolium</i> (Stem and leaf)	E-091	<i>Citrus grandis</i> (Epicarp and mesocarp)
E-017	<i>Gentiana scabra</i> (Root and rhizome)	E-042	<i>Firmiana simplex</i> (Leaf)	E-067	<i>Pachyrhizus erosus</i> (Root bark)	E-092	<i>Amaranthus mangostanus</i> (Root)
E-018	<i>Gentiana triflora</i> (Fruiting body)	E-043	<i>Impatiens balsamina</i> (Root)	E-068	<i>Polygonum orientale</i> (Flower)	E-093	<i>Capsicum frutescens</i> (Stem)
E-019	<i>Melia toosendan</i> (Leaf)	E-044	<i>Pseudostellaria heterophylla</i> (Root)	E-069	<i>Cucurbita moschata</i> (Leaf)	E-094	<i>Vigna sinensis</i> (Shell)
E-020	<i>Cyperus rotundus</i> (Herb)	E-045	<i>Allium cepa</i> (Bulb)	E-070	<i>Apium graveolens</i> var. <i>dulce</i> (Stem and leaf)	E-095	<i>Catalpa ovata</i> (Leaf)
E-021	<i>Campsis grandiflora</i> (Root)	E-046	<i>Nelumbo nucifera</i> (Stamen)	E-071	<i>Castanea mollissima</i> (Epicarp)	E-096	<i>Prunus salicina</i> (Fruit)
E-022	<i>Humulus scandens</i> (Stem and leaf)	E-047	<i>Vitis vinifera</i> (Fruit)	E-072	<i>Trachycarpus fortunei</i> (Root)	E-097	<i>Tasminum sambac</i> (Flower)
E-023	<i>Datura metel</i> (Root)	E-048	<i>Arachis hypogaea</i> (Branch and leaf)	E-073	<i>Nelumbo nucifera</i> (Leaf base)	E-098	<i>Oryza sativa</i> (Kernel)
E-024	<i>Commelina communis</i> (Herb)	E-049	<i>Platycodon grandiflorum</i> (Root)	E-074	<i>Pyrus bretschneideri</i> (Peel)	E-099	<i>Luffa cylindrica</i> (Stem)
E-025	<i>Disopyros kaki</i> (Calyx)	E-050	<i>Cucumis melo</i> (Flower)	E-075	<i>Juglans regia</i> (Endocarp)	E-100	<i>Malus asiatica</i> (Fruit)

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
F-001	<i>Euphorbia longan</i> (Peel)	F-026	<i>Lycium chinense</i> (Leaf)	F-051	<i>Ananas comosus</i> (Peel)	F-076	<i>Pennisetum alopecuroides</i> (Aerial part)
F-002	<i>Allium fistulosum</i> (Stem)	F-027	<i>Cephalanoplos segetum</i> (Stem and leaf)	F-052	<i>Cycas revoluta</i> (Leaf)	F-077	<i>Gossypium herbaceum</i> (Root)
F-003	<i>Citrus limonia</i> (Fruit)	F-028	<i>Canna indica</i> (Flower)	F-053	<i>Cinnamomum parthenoxylon</i> (Leaf)	F-078	<i>Lactuca sativa</i> (Stem and leaf)

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
F-004	<i>Sapium sebiferum</i> (Leaf)	F-029	<i>Helianthus annuus</i> (Flower)	F-054	<i>Pennisetum alopecuroides</i> (Root)	F-079	<i>Acalypha dustralis</i> (Herb)
F-005	<i>Arachis hypogaea</i> (Seed)	F-030	<i>Dolichos lablab</i> (Stem)	F-055	<i>Physalis pubescens</i> (Fruit)	F-080	<i>Spinacia oleracea</i> (Stem and leaf)
F-006	<i>Citrullus vulgaris</i> (Fruit)	F-031	<i>Rosa multiflora</i> (Leaf)	F-056	<i>Eucommia ulmoides</i> (Leaf)	F-081	<i>Malus pumila</i> (Leaf)
F-007	<i>Pyrus bretschneideri</i> (Leaf)	F-032	<i>Momordica charantia</i> (Stem)	F-057	<i>Brassica campestris</i> var. <i>oleifera</i> (Seed)	F-082	<i>Bidens bipinnata</i> (Herb)
F-008	<i>Juglans regia</i> (Leaf)	F-033	<i>Tribulus terrestris</i> (Stem and leaf)	F-058	<i>Lagenaria siceraria</i> var. <i>gourda</i> (Fruit)	F-083	<i>Phragmites communis</i> (Immature stem)
F-009	<i>Helianthus annuus</i> (Leaf)	F-034	<i>Prunus armeniaca</i> (Leaf)	F-059	<i>Trifolium repens</i> (Aerial part)	F-084	<i>Luffa cylindrica</i> (Seed)
F-010	<i>Phytolacca acinosa</i> (Flower)	F-035	<i>Phragmites communis</i> (Leaf)	F-060	<i>Cocos nucifera</i> (Endocarp)	F-085	<i>Podocarpus macrophyllus</i> (Leaf)
F-011	<i>Triticum aestivum</i> (Seed)	F-036	<i>Benincasa hispida</i> (Leaf)	F-061	<i>Punica granatum</i> (Flower)	F-086	<i>Cyperus michelianus</i> (Herb)
F-012	<i>Euphorbia longan</i> (Seed)	F-037	<i>Artemisia sieversiana</i> (Aerial part)	F-062	<i>Setaria faberii</i> (Aerial part)	F-087	<i>Castanea mollissima</i> (Bract)
F-013	<i>Citrus limonia</i> (Peel)	F-038	<i>Zea mays</i> (Spike)	F-063	<i>Canna indica</i> (Rhizome)	F-088	<i>Rumex madaio</i> (Root)
F-014	<i>Ficus carica</i> (Fruit)	F-039	<i>Pisum sativum</i> (Seed)	F-064	<i>Fortunella margarita</i> (Fruit)	F-089	<i>Kyllinga brevifolia</i> (Herb)
F-015	<i>Pyrus bretschneideri</i> (Branch)	F-040	<i>Helianthus annuus</i> (Root)	F-065	<i>Gossypium herbaceum</i> (Epicarp)	F-090	<i>Medicago sativa</i> (Aerial part)
F-016	<i>Ulmus pumila</i> (Leaf)	F-041	<i>Setaria geniculata</i> (Stem, flower and leaf)	F-066	<i>Rorippa montana</i> (Flower, fruit and leaf)	F-091	<i>Brassica campestris</i> var. <i>oleifera</i> (Stem and leaf)
F-017	<i>Helianthus annuus</i> (Flower receptacle)	F-042	<i>Vigna sinensis</i> (Root)	F-067	<i>Commelina diffusa</i> (Stem, flower and leaf)	F-092	<i>Oenanthe javanica</i> (Herb)
F-018	<i>Rosa multiflora</i> (Flower)	F-043	<i>Rosa multiflora</i> (Branch)	F-068	<i>Oxalis corniculata</i> (Stem, flower and leaf)	F-093	<i>Eragrostis tenella</i> (Aerial part)
F-019	<i>Benincasa hispida</i> (Stem)	F-044	<i>Dolichos lablab</i> (Leaf)	F-069	<i>Typha angustata</i> (Spike)	F-094	<i>Juglans regia</i> (Immature fruit)
F-020	<i>Momordica charantia</i> (Leaf)	F-045	<i>Setaria italica</i> (Kernel)	F-070	<i>Allium tuberosum</i> (Root and scaly bulb ?)	F-095	<i>Eleusine indica</i> (Aerial part)
F-021	<i>Trachycarpus wagnerianus</i> (Fruit)	F-046	<i>Momordica charantia</i> (Root)	F-071	<i>Chrysanthemum coronarium</i> var. <i>spatiosum</i> (Leaf)	F-096	<i>Zea mays</i> (Leaf)
F-022	<i>Vigna sinensis</i> (Leaf)	F-047	<i>Ginkgo biloba</i> (Seed)	F-072	<i>Glycine soja</i> (Stem, leaf and fruit)	F-097	<i>Celocia argentina</i> (Stem, leaf, flower and root)
F-023	<i>Abutilon theophrasti</i> (Root)	F-048	<i>Helianthus annuus</i> (Pericarp)	F-073	<i>Castanea mollissima</i> (Leaf)	F-098	<i>Physalis peruviana</i> (Aerial part)
F-024	<i>Prunus armeniaca</i> (Branch)	F-049	<i>Ananas comosus</i> (Leaf)	F-074	<i>Chenopodium ambosioides</i> (Spike and stem)	F-099	<i>Punica granatum</i> (Acid fruit)
F-025	<i>Physalis pubescens</i> (Stem and leaf)	F-050	<i>Allium fistulosum</i> (Fibrous root)	F-075	<i>Leptochloa chinensis</i> (Herb)	F-100	<i>Corchorus acutangulus</i> (Stem and leaf)

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
G-001	<i>Zanthoxylum bungeanum</i> (Leaf)	G-026	<i>Hydnocarpus anthelmintica</i> (Seed)	G-051	<i>Populus davidiana</i> (Wood)	G-076	<i>Humulus scandens</i> (Flower and leaf)
G-002	<i>Lycopersicon esculentum</i> (Fresh fruit)	G-027	<i>Phyllanthus urinaria</i> (Aerial part)	G-052	<i>Ziziphus jujuba</i> var. <i>inermis</i> (Leaf)	G-077	<i>Thesium chinense</i> (Aerial part)
G-003	<i>Reineckea carnea</i> (Herb)	G-028	<i>Euphorbia lathyris</i> (Seed)	G-053	<i>Polygonum chinense</i> (Herb)	G-078	<i>Brassica caulorapa</i> (Leaf)
G-004	<i>Junicus setchuensis</i> var. <i>effusoides</i> (Stem and leaf)	G-029	<i>Pteroxygonum giraldii</i> (Root)	G-054	<i>Serissa serissoides</i> (Stem and leaf)	G-079	<i>Clinopodium chinense</i> (Aerial part)
G-005	<i>Spiranthes sinensis</i> (Aerial part)	G-030	<i>Spinacia oleracea</i> (Fruit)	G-055	<i>Sweita pulchella</i> (Stem and leaf)	G-080	<i>Pinus tabulaeformis</i> (Leaf)
G-006	<i>Ziziphus jujuba</i> var. <i>inermis</i> (Leaf)	G-031	<i>Periploca forrestii</i> (Root or stem)	G-056	<i>Actinidia chinensis</i> (Leaf)	G-081	<i>Cyanotis vaga</i> (Aerial part)
G-007	<i>Knoxia valerianoides</i> (Root)	G-032	<i>Macreaya cordata</i> (Fruit)	G-057	<i>Ajuga ciliata</i> (Herb)	G-082	<i>Cinnamomum parthenoxylon</i> (Fruit)
G-008	<i>Murraya paniculata</i> (Branch and leaf)	G-033	<i>Ardisia japonica</i> (Herb)	G-058	<i>Curdus crispus</i> (Herb)	G-083	<i>Salvia plebeia</i> (Herb)
G-009	<i>Similax china</i> (Rhizome)	G-034	<i>Phaseolus radiatus</i> (Leaf)	G-059	<i>Commelia benghalensis</i> (Stem and leaf)	G-084	<i>Musa basjoo</i> (Leaf)
G-010	<i>Achyranthes aspera</i> (Aerial part)	G-035	<i>Phragmites communis</i> (Flower)	G-060	<i>Humulus lupulus</i> (Female flower)	G-085	<i>Ipomoea batatas</i> (Leaf)
G-011	<i>Alangium chinense</i> (Root)	G-036	<i>Choerospondias axillaris</i> (Fruit)	G-061	<i>Daphne genkwa</i> (Leaf and Bud)	G-086	<i>Achiranthos bidentata</i> (Root and rhizome)
G-012	<i>Fagopyrum esculentum</i> (Seed)	G-037	<i>Gomphrena globosa</i> (Flower)	G-062	<i>Prunus pseudocerasus</i> (Leaf)	G-087	<i>Celocia cristata</i> (Stem and leaf)
G-013	<i>Ficus pumila</i> (Fruit)	G-038	<i>Sedum aizoon</i> (Aerial part)	G-063	<i>Senecio Scandens</i> (Herb)	G-088	<i>Ilex chinensis</i> (Fruit)
G-014	<i>Amaranthus ascendens</i> (Spike and seed)	G-039	<i>Paulownia fortunei</i> (Fruit)	G-064	<i>Polygonum perfoliatum</i> (Herb)	G-089	<i>Cyperus alternifolius</i> (Aerial part)
G-015	<i>Dysosma pleiantha</i> (Root and rhizome)	G-040	<i>Populus davidiana</i> (Leaf)	G-065	<i>Vicia faba</i> (Seed)	G-090	<i>Aster fastigiatus</i> (Herb)
G-016	<i>Mahonia bealei</i> (Stem)	G-041	<i>Paederia scandens</i> (Root and stem)	G-066	<i>Typha angustata</i> (Herb)	G-091	<i>Ricinus communis</i> (Leaf)
G-017	<i>Adiantum caudatum</i> (Herb)	G-042	<i>Pterispermum heterophyllum</i> (Root)	G-067	<i>Glycine soja</i> (Seed)	G-092	<i>Rhododendron arboreum</i> (Flower or leaf)
G-018	<i>Nerium indicum</i> (Leaf)	G-043	<i>Mallotus apelta</i> (Leaf)	G-068	<i>Salsola ruthenica</i> (Herb)	G-093	<i>Artemisia annua</i> (Aerial part)
G-019	<i>Alocasia odor</i> (Rhizome)	G-044	<i>Clinopodium chinense</i> (Stem and leaf)	G-069	<i>Ilex sp.</i> (Leaf)	G-094	<i>Mosla grosseserrata</i> (Stem and leaf)
G-020	<i>Vitex negundo</i> (Fruit)	G-045	<i>Eucalyptus robusta</i> (Leaf)	G-070	<i>Ulmus pumila</i> (Bark or root bark)	G-095	<i>Calystegia japonica</i> (Aerial part)
G-021	<i>Stellaria media</i> (Stem and leaf)	G-046	<i>Vicia sativa</i> (Aerial part)	G-071	<i>Erigeron annuus</i> (Herb)	G-096	<i>Ainsliaea fragrans</i> (Herb)
G-022	<i>Hibiscus rosa-sinensis</i> (Flower)	G-047	<i>Wedelia chinensis</i> (Herb)	G-072	<i>Equisetum arvense</i> (Aerial part)	G-097	<i>Tagetes erecta</i> (Flower)
G-023	<i>Vladimiria berardioides</i> (Root)	G-048	<i>Selaginella unicinata</i> (Herb)	G-073	<i>Pinus koeiensis</i> (Seed)	G-098	<i>Sapium sebiferum</i> (Seed)
G-024	<i>Aralia chinensis</i> (Stem)	G-049	<i>Orobanchae coerul-e-scens</i> (Root or stem)	G-074	<i>Camptotheca acuminata</i> (Fruit)	G-099	<i>Antidesma bunius</i> (Fruit)
G-025	<i>Dioscorea nipponica</i> (Rhizome)	G-050	<i>Trollius chinensis</i> (Flower)	G-075	<i>Tagetes erecta</i> (Leaf)	G-100	<i>Cocos nucifera</i> (Albumen)

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
H-001	<i>Aconitum carmichaeli</i> (Root)	H-026	<i>Aconitum kusnezoffii</i> (Rhizome)	H-051	<i>Solanum lyratum</i> (Fruit)	H-076	<i>Dioscorea zingiberensis</i> (Rhizome)
H-002	<i>Thymus serpyllum</i> (Herb)	H-027	<i>Rosa davurica</i> (Fruit)	H-052	<i>Mirabilis jalapa</i> (Stem and leaf)	H-077	<i>Metaplexis japonica</i> (Pericarp)
H-003	<i>Poncirus trifoliata</i> (Immature fruit)	H-028	<i>Stephania delaveyi</i> (Rhizome)	H-053	<i>Silybum marianum</i> (Leaf)	H-078	<i>Beta vulgaris</i> var. <i>cicla</i> (Leaf)
H-004	<i>Euphorbia hirta</i> (Herb)	H-029	<i>Citrus tangerina</i> (Seed)	H-054	<i>Brassica rapa</i> (Rhizome)	H-079	<i>Hyoscyamus niger</i> (Seed)
H-005	<i>Rorippa montana</i> (Herb)	H-030	<i>Ardisia crispa</i> (Root and rhizome)	H-055	<i>Pterocarya stenoptera</i> (Leaf)	H-080	<i>Entada phaseoloides</i> (Seed)
H-006	<i>Sambucus williamsii</i> (Stem and branch)	H-031	<i>Gelsemium elegans</i> (Herb)	H-056	<i>Helleborus thibetanus</i> (Root)	H-081	<i>Lagenaria siceraria</i> var. <i>depressa</i> (Seed)
H-007	<i>Entada phaseoloides</i> (Flower and stem)	H-032	<i>Toddalia asiatica</i> (Root)	H-057	<i>Alternanthera philoxeroides</i> (Stem and leaf)	H-082	<i>Trichosanthes cucumeroides</i> (Root)
H-008	<i>Desmodium pulchellum</i> (Aerial part)	H-033	<i>Saccharum sinensis</i> (Stem)	H-058	<i>Veronica didyma</i> (Herb)	H-083	<i>Hovenia dulcis</i> (Leaf)
H-009	<i>Rostellularia procumbens</i> (Herb)	H-034	<i>Tripterygium wilfordii</i> (Root)	H-059	<i>Fagopyrum esculentum</i> (Stem)	H-084	<i>Glechoma longituba</i> (Herb)
H-010	<i>Oldenlandia chrysotricha</i> (Herb)	H-035	<i>Mirabilis jalapa</i> (Rhizome)	H-060	<i>Heleocharis dulcis</i> (Stem)	H-085	<i>Silybum marianum</i> (Seed)
H-011	<i>Kummerowia striata</i> (Herb)	H-036	<i>Brassica caulorapa</i> (Stem)	H-061	<i>Catalpa bungei</i> (Leaf)	H-086	<i>Abelmoschus manihot</i> (Flower)
H-012	<i>Chimonanthus praecox</i> (Bud)	H-037	<i>Juniperus formosana</i> (Fruit)	H-062	<i>Narcissus tazetta</i> (Bulb)	H-087	<i>Beta vulgaris</i> var. <i>cicla</i> (Seed)
H-013	<i>Damnacanthus indicus</i> (Herb)	H-038	<i>Agaricus campestris</i> (Fruiting body)	H-063	<i>Pueraria lobata</i> (Leaf)	H-088	<i>Clinopodium gracile</i> (Herb)
H-014	<i>Carpesium abrotanoides</i> (Fruit)	H-039	<i>Hibiscus syriacus</i> (Leaf)	H-064	<i>Lagenaria siceraria</i> (Fruit)	H-089	<i>Hovenia dulcis</i> (Herb)
H-015	<i>Caryopteris incana</i> (Herb)	H-040	<i>Citrus junos</i> (Fruit)	H-065	<i>Similax china</i> (Leaf)	H-090	<i>Fritillaria unibracteata</i> (Bulb)
H-016	<i>Schefflera arboricola</i> (Stem and leaf)	H-041	<i>Polygonum hydropiper</i> (Aerial part)	H-066	<i>Vitex trifolia</i> (Leaf)	H-091	<i>Cucumis sativus</i> (Stem)
H-017	<i>Ilex asprella</i> (Root)	H-042	<i>Sambucus javanica</i> (Root)	H-067	<i>Quercus acutissima</i> (Fruit)	H-092	<i>Potentilla chinensis</i> (Aerial part)
H-018	<i>Croton crassifolius</i> (Root)	H-043	<i>Carpesium abrotanoides</i> (Stem and leaf)	H-068	<i>Sesamum indicum</i> (Pericarp)	H-093	<i>Gleditsia sinensis</i> (Leaf)
H-019	<i>Eupatorium odoratum</i> (Herb)	H-044	<i>Piper nigrum</i> (Fruit)	H-069	<i>Artemisia anomala</i> (Herb)	H-094	<i>Solanum indicum</i> (Fruit)
H-020	<i>Chloranthus serratus</i> (Root)	H-045	<i>Pelargonium graveolens</i> (Leaf)	H-070	<i>Orostachys fimbriatus</i> (Herb)	H-095	<i>Marsdenia tenacissima</i> (Stem)
H-021	<i>Camellia sinensis</i> (Leaf)	H-046	<i>Capsella bursa-pastoris</i> (Aerial part)	H-071	<i>Eupatorium chinense</i> (Root)	H-096	<i>Triticum aestivum</i> (Immature leaf)

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
H-022	<i>Adiantum flabellulatum</i> (Rhizome)	H-047	<i>Gynura bicor</i> (Leaf)	H-072	<i>Actinidia arguta</i> (Leaf)	H-097	<i>Sapindus mukorossi</i> (Fruit)
H-023	<i>Caragana sinica</i> (Root)	H-048	<i>Saccharum sinensis</i> (Stem bark)	H-073	<i>Cassi occidentalis</i> (Seed)	H-098	<i>Pueraria lobata</i> (Stem)
H-024	<i>Maghanian philippinensis</i> (Root)	H-049	<i>Malva verticillata</i> (Stem and leaf)	H-074	<i>Heleocharis dulcis</i> (Stem)	H-099	<i>Pterocarya stenoptera</i> (Fruit)
H-025	<i>Camptotheca acuminata</i> (Leaf)	H-050	<i>Ganoderma lucidum</i> (Fruiting body)	H-075	<i>Gastrodia elata</i> (Rhizome)	H-100	<i>Ferula assafoetida</i> (Resin)

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
I-001	<i>Crataegus pinnatifida</i> var. <i>major</i> (Stem and leaf)	I-026	<i>Pyracantha fortuneana</i> (Fruit)	I-051	<i>Phyllostachys nigra</i> (Rhizome)	I-076	<i>Bidens tripartita</i> (Herb)
I-002	<i>Cassytha filiformis</i> (Aerial part)	I-027	<i>Nandina domestica</i> (Fruit)	I-052	<i>Michelia champaca</i> (Fruit)	I-077	<i>Mangifera indica</i> (Kernel)
I-003	<i>Peristrophe japonica</i> (Herb)	I-028	<i>Acer sinense</i> (Root bark)	I-053	<i>Jasminum officinale</i> var. <i>grandiflorum</i> (Bud)	I-078	<i>Vitex negundo</i> (Fruit)
I-004	<i>Phaseolus calcaratus</i> (Leaf)	I-029	<i>Lamium amplexicaule</i> (Leaf)	I-054	<i>Ilex cirbyta</i> (Fruit)	I-079	<i>Phyllanthus emblica</i> (Fruit)
I-005	<i>Abelmoschus manihot</i> (Leaf)	I-030	<i>Dioscorea japonica</i> (Brood bud)	I-055	<i>Phyllostachys pubescens</i> (Shoot)	I-080	<i>Corydalis decumbens</i> (Rhizome)
I-006	<i>Panicum miliaceum</i> (Seed)	I-031	<i>Cercis chinensis</i> (Fruit)	I-056	<i>Evodia lepta</i> (Root)	I-081	<i>Malva verticillata</i> (Seed)
I-007	<i>Sagittaria sagittifolia</i> (Stem)	I-032	<i>Glycine max</i> (Seed)	I-057	<i>Celastrus orbiculatus</i> (Root)	I-082	<i>Panax pseudo-ginseng</i> var. <i>japonicus</i> (Rhizome)
I-008	<i>Cucumis sativus</i> (Root)	I-033	<i>Hemerocallis falva</i> var. <i>kwanso</i> (Bud)	I-058	<i>Mangifera indica</i> (Fruit)	I-083	<i>Glochidion puberwn</i> (Fruit)
I-009	<i>Croton tiliifolium</i> (Fruit)	I-034	<i>Buxus microphylla</i> var. <i>sinica</i> (Stem and branch)	I-059	<i>Clematis henryi</i> (Root)	I-084	<i>Anemone raddeana</i> (Rhizome)
I-010	<i>Dioscorea japonica</i> (Stem)	I-035	<i>Duchesnea indica</i> (Root)	I-060	<i>Ophioglossum pedunculatum</i> (Aerial part)	I-085	<i>Gleomo gynandra</i> (Seed)
I-011	<i>Agave sisalana</i> (Leaf)	I-036	<i>Rhododendron simsii</i> (Root)	I-061	<i>Achillea alpina</i> (Herb)	I-086	<i>Dactylicapnos scandens</i> (Root)
I-012	<i>Basella rubra</i> (Aerial part)	I-037	<i>Capsicum frutescens</i> var. <i>conoides</i> (Fruit)	I-062	<i>Lysinachi clethroides</i> (Herb)	I-087	<i>Abrus precatorius</i> (Seed)
I-013	<i>Galiun verum</i> (Aerial part)	I-038	<i>Lagerstroemia indica</i> (Root)	I-063	<i>Pholidota chinensis</i> (Bulb)	I-088	<i>Prunus pseudocerasus</i> (Kernel)
I-014	<i>Quercus acutissima</i> (Peel)	I-039	<i>Cerastium viscosum</i> (Aerial part)	I-064	<i>Ilex chinensis</i> (Leaf)	I-089	<i>Iris pallasii</i> (Seed)
I-015	<i>Ceratopteris thalictroides</i> (Aerial part)	I-040	<i>Immatureia japonica</i> (Herb)	I-065	<i>Scopolia acutangula</i> (Rhizome)	I-090	<i>Zanthoxylum avicennae</i> (Root)
I-016	<i>Colocasia esculenta</i> (Tuber)	I-041	<i>Rhododendron simsii</i> (Leaf)	I-066	<i>Gossampinus malabarica</i> (Flower)	I-091	<i>Valeriana officinalis</i> (Root and rhizome)
I-017	<i>Asparagus cochinchinensis</i> (Root)	I-042	<i>Cyrtomium caryotideum</i> (Rhizome)	I-067	<i>Adina rubella</i> (Stem)	I-092	<i>Daucus carota</i> (Fruit)
I-018	Not identified	I-043	<i>Fragaria chiloensis</i> var. <i>ananassa</i> (Fruit)	I-068	<i>Potentilla discolor</i> (Herb)	I-093	<i>Loropetalum chinense</i> (Stem)
I-019	<i>Osmanthus fragrans</i> (Root and root bark)	I-044	<i>Cyrtomium fortunei</i> (Rhizome)	I-069	<i>Helicteres angustifolia</i> (Root)	I-094	<i>Gnetum parvifolium</i> (Stem)
I-020	<i>Sesbania cannabina</i> (Leaf)	I-045	<i>Dryopteris championii</i> (Rhizome)	I-070	<i>Ocimum basilicum</i> (Herb)	I-095	<i>Melandryum viscidulum</i> var. <i>szechuanense</i> (Root)
I-021	Not identified	I-046	<i>Cyclosorus acuminatus</i> (Rhizome)	I-071	<i>Thalictrum foliolosum</i> (Rhizome and root)	I-096	<i>Buddleia lindheyana</i> (Herb)
I-022	<i>Dichondra repens</i> (Leaf)	I-047	<i>Buxus microphylla</i> var. <i>sinica</i> (Leaf)	I-072	<i>Hosta plangaginis</i> (Leaf)	I-097	<i>Stenoloma chusanum</i> (Aerial part)
I-023	<i>Hibiscus mutabilis</i> (Leaf)	I-048	<i>Fritillaria ussuriensis</i> (Bulb)	I-073	<i>Lepidogrammitis drymoglossoides</i> (Herb)	I-098	<i>Lythrum salicaria</i> (Herb)
I-024	Not identified	I-049	<i>Nandina domestica</i> (Leaf)	I-074	<i>Isodon striatus</i> (Herb)	I-099	<i>Aconitum brachypodium</i> (Root)
I-025	<i>Hedera nepalensis</i> var. <i>sinensis</i> (Stem and leaf)	I-050	<i>Pyracantha fortuneana</i> (Leaf)	I-075	<i>Ranunculus sceleratus</i> (Herb)	I-100	<i>Lysimachia klattiana</i> (Aerial part)

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
J-001	<i>Saururus chinensis</i> (Herb)	J-026	<i>Carica papaya</i> (Stem and leaf)	J-051	<i>Berberis sargentiana</i> (Root)	J-076	<i>Allium nipponicum</i> (Bulb)
J-002	<i>Oldenlandia corymbosa</i> (Herb)	J-027	<i>Camellia oleifera</i> (Seed)	J-052	<i>Sapindus mukorossi</i> (Fruit)	J-077	<i>Averrhoa carambola</i> (Fruit)
J-003	<i>Gnaphalium affine</i> (Aerial part)	J-028	<i>Camellia oleifera</i> (Aerial part)	J-053	<i>Jasminum nudiflorum</i> (Root)	J-078	<i>Rubus corchorifolius</i> (Stem)
J-004	<i>Celtis bungeana</i> (Stem)	J-029	<i>Wisteria sinensis</i> (Seed)	J-054	<i>Ligustrum quihoui</i> (Leaf)	J-079	<i>Rubus corchorifolius</i> (Root)
J-005	<i>Rauwolfia verticillata</i> (Stem)	J-030	<i>Camellia japonica</i> (Leaf)	J-055	<i>Carya cathayensis</i> (Leaf)	J-080	<i>Limonium sinensis</i> (Root)
J-006	<i>Ardisia crenata</i> (Root)	J-031	<i>Hypericum chinense</i> (Aerial part)	J-056	<i>Carya cathayensis</i> (Epicarp)	J-081	<i>Rosa davurica</i> (Fruit)
J-007	<i>Wilstroemia indica</i> (Root)	J-032	<i>Zelkova schneideriana</i> (Leaf)	J-057	<i>Semiaquilegia adoxoides</i> (Leaf)	J-082	<i>Lactuca sativa</i> (Seed)
J-008	<i>Rhododendron dauricum</i> (Flower)	J-033	<i>Jasminum nudiflorum</i> (Stem and leaf)	J-058	<i>Elaeagnus angustifolia</i> (Fruit)	J-083	<i>Belamcanda chinensis</i> (Rhizome)
J-009	<i>Thladiantha dubia</i> (Fruit)	J-034	<i>Euonymus bungeanus</i> (Branch and leaf)	J-059	<i>Tulipa edulis</i> (Bulb)	J-084	<i>Berchmia lineata</i> (Root and stem)
J-010	<i>Taxus cuspidata</i> (Leaf)	J-035	<i>Viburnum dilatatum</i> (Stem and leaf)	J-060	<i>Rhus chinensis</i> (Root)	J-085	<i>Urena lobata</i> (Flower)
J-011	<i>Vicia faba</i> (Stem)	J-036	<i>Ulmus parvifolia</i> (Stem and leaf)	J-061	<i>Rhus sylvestris</i> (Root)	J-086	<i>Brassica rapa</i> (Seed)
J-012	<i>Zanthoxylum planispinum</i> (Leaf)	J-037	<i>Alchornea davidi</i> (Stem and leaf)	J-062	<i>Rhus sylvestris</i> (Leaf)	J-087	<i>Milletia reticulata</i> (Stem and leaf)
J-013	<i>Aucuba chinensis</i> (Leaf)	J-038	<i>Viburnum macrocephalum</i> (Stem)	J-063	<i>Lygodium japonicum</i> (Root and rhizome)	J-088	<i>Milletia reticulata</i> (Root)
J-014	<i>Lycoris radiata</i> (Bulb)	J-039	<i>Narcissus tazetta</i> var. <i>chinensis</i> (Flower)	J-064	<i>Xylosma japonicum</i> (Bark)	J-089	<i>Silene conoidea</i> (Aerial part)
J-015	<i>Camellia japonica</i> (Flower)	J-040	<i>Citrus medica</i> (Leaf)	J-065	<i>Castanopsis sclerophylla</i> (Leaf)	J-090	<i>Jasminum sambac</i> (Root)
J-016	<i>Eriobotrya japonica</i> (Flower)	J-041	<i>Viburnum dilatatum</i> (Fruit)	J-066	<i>Elaeagnus pungens</i> (Leaf)	J-091	<i>Rosa roxburghii</i> (Fruit)
J-017	<i>Cephalotaxus fortunei</i> (Leaf)	J-042	<i>Ficus pumila</i> (Stem and leaf)	J-067	Not identified	J-092	<i>Rubia cordifolia</i> (Root)
J-018	<i>Solanum nigrum</i> (Root)	J-043	<i>Cryptomeria fortunei</i> (Leaf)	J-068	<i>Chaenomeles lagenaria</i> (Leaf)	J-093	<i>Medicago falcata</i> (Herb)
J-019	<i>Zebrina pendula</i> (Aerial part)	J-044	<i>Rohdea japonica</i> (Leaf)	J-069	<i>Cephalotaxus fortunei</i> (Root)	J-094	<i>Daucus carota</i> var. <i>sativa</i> (Fruit)
J-020	<i>Crotalaria mucronata</i> (Stem and leaf)	J-045	<i>Celtis chinensis</i> (Leaf)	J-070	<i>Artemisia selengensis</i> (Stem and leaf)	J-095	<i>Avena fatura</i> (Herb)
J-021	<i>Zanthoxylum planispinum</i> (Root)	J-046	<i>Phoebe shearerii</i> (Root)	J-071	<i>Edgeworthia chrysantha</i> (Bud)	J-096	<i>Elaeagnus pungens</i> (Root)
J-022	<i>Cunninghamia lanceolata</i> (Leaf)	J-047	<i>Xylosma japonicum</i> (Leaf)	J-072	<i>Cymbidium ensifolium</i> (Leaf)	J-097	<i>Gardenia jasminoides</i> (Leaf)
J-023	<i>Coix lachryma-jobi</i> (Leaf)	J-048	<i>Juglans cathayensis</i> (Kernel)	J-073	<i>Cymbidium ensifolium</i> (Flower)	J-098	<i>Agastache rugosa</i> (Aerial part)
J-024	<i>Phoebe shearerii</i> (Leaf)	J-049	<i>Rhus chinensis</i> (Fruit)	J-074	<i>Mnium cuspidatum</i> (Herb)	J-099	<i>Fritillaria verticillata</i> var. <i>thunbergii</i> (Bulb)
J-025	<i>Liquidambar orientalis</i> (Leaf)	J-050	<i>Rohdea japonica</i> (Root)	J-075	<i>Juniperus rigida</i> (Leaf)	J-100	<i>Fibraurea recisa</i> (Stem)

Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)	Sample No.	Plant (part used)
K-001	Not identified	K-003	Not identified	K-005	<i>Rubus hirsutus</i> (Leaf)	K-007	<i>Linum usitatissimum</i> (Seed)
K-002	<i>Lycoris aurea</i> (Bulb)	K-004	<i>Tagetes patula</i> (Flower)	K-006	<i>Limonium bicolor</i> (Root)	K-008	<i>Cardamine lyrata</i> (Aerial part)

25 µg/ml. Fig. 1 shows the representative ESR spectra of solvent control and ethanol extract with either poor or potent O₂^{•-} scavenging activity. Based on the data, we picked up four edible herbal extracts for further analyses. They are No.A-058 (Peel of *Punica granatum*), No.C-037 (Bud of *Syzygium aromaticum*), No.I-077 (Kernel of *Mangifera indica*), and No.I-079 (Fruit of *Phyllanthus emblica*). As shown in Fig. 2, these four extracts

contained abundantly polyphenols, whilst herbs with poor O₂^{•-} scavenging activity (5% or less reduction of signal intensity of DMPO-OOH at a fixed concentration of 25 µg/ml) contained a little amount of polyphenols. The results indicate that the O₂^{•-} scavenging activity was apparently reflected by the polyphenols content.

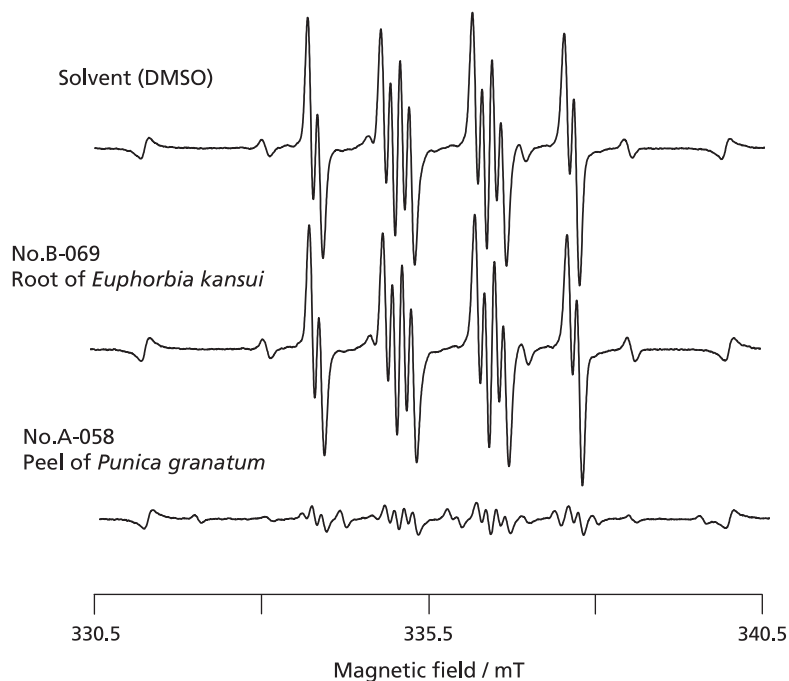


Fig. 1. The Representative ESR spectra of DMPO-OOH (for $O_2^{\cdot-}$ determination) obtained by the addition of solvent control and ethanol extracts of *Euphorbia kansui* (root) and *Punica granatum* (peel) at a concentration of 25 $\mu\text{g/ml}$.

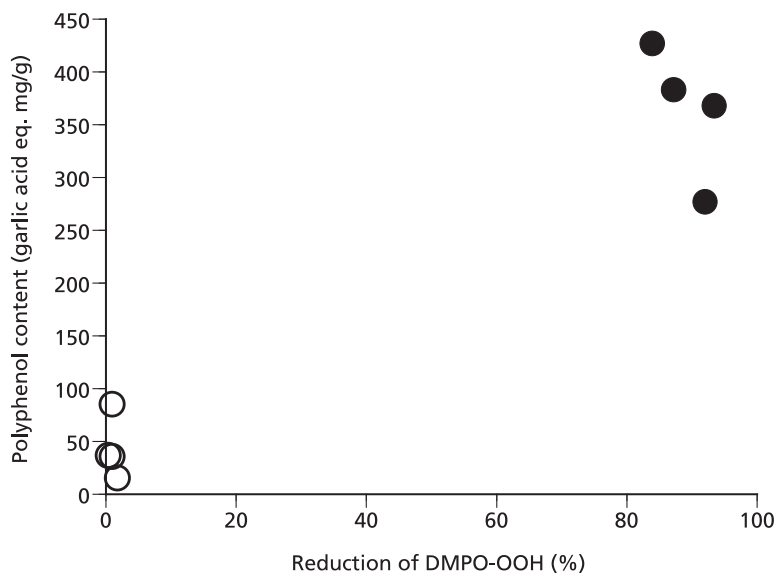


Fig. 2. Total polyphenol contents of eight herbal extracts. Solid circles and open circles indicate extracts with potent activity (80% or more reduction of signal intensity of DMPO-OOH a fixed concentration of 25 $\mu\text{g/ml}$) and poor activity (5% or less reduction of signal intensity of DMPO-OOH at a fixed concentration of 25 $\mu\text{g/ml}$), respectively. Solid circles are the extracts of peel of *Punica granatum*, bud of *Syzygium aromaticum*, kernel of *Mangifera indica*, and fruit of *Phyllanthus emblica*. Open circles are the extracts of kernel of *Prunus armeniaca*, root of *Oryza sativa*, root of *Euphorbia kansui*, and seed of *Ricinus communis*.

Antioxidant Properties of Herbal Extracts Selected from Screening for Potent Scavenging Activity against $O_2^{\cdot-}$

ESR analyses of $\cdot\text{OH}$ from Fenton reaction and from photolysis of H_2O_2 by UV-irradiation were conducted. The assays used in this study were essentially identical to those described in a previous

paper.⁽²¹⁾ In brief for the former assay, 50 μl of 2 mM H_2O_2 dissolved in 0.1 M phosphate buffer (pH 7.4), 50 μl of 8.9 mM DMPO dissolved in pure water, 50 μl of sample dissolved in pure water and 50 μl of 0.2 mM FeSO_4 dissolved in pure water were placed in a test tube and mixed. Each mixture was transferred to an ESR spectrometry cell and the DMPO-OH spin adduct was

quantified 113 s after the addition of FeSO₄. For the latter assay, a reaction mixture consisting of 440 µl of 100 mM H₂O₂ prepared in 25 mM phosphate buffer (pH 7.4), 10 µl of 111.25 mM DMPO dissolved in pure water and 50 µl of sample dissolved in pure water was exposed to 254 nm UV irradiation at 4 W for 1 min at a distance of 12 cm. Then the ESR spectrum of DMPO-OH was measured. When DMPO was added to a solution of the Fenton reaction system, the spin adduct DMPO-OH was formed. A reduction in the signal intensity of DMPO-OH by the addition of selected four herbal extracts likely reflects an ability to scavenge [•]OH. This was also confirmed by the assay of photolysis of H₂O₂ by UV-irradiation. In the assay, the ESR signal of DMPO-OH was reduced by adding any of the four herbal extracts, depending on the concentration. This indicates that any of the extracts has the ability to directly scavenge [•]OH.

As for the heat resistance of the antioxidant potency of the four herbal extracts, the effect of heat (100°C) exposure on the O₂^{•-}- and [•]OH-scavenging activity of the extracts was examined. While the O₂^{•-}-scavenging activity of 6.25 µg/ml L-ascorbic acid as a reference agent, at which concentration L-ascorbic acid exerted scavenging activity comparable to 25 µg/ml herbal extract, was completely inactivated after heat exposure for 30 min, the activities of 25 µg/ml extracts from *P. granatum* (peel), *M. indica* (kernel) and *P. emblica* (fruit) were reduced by only about 20% even after

heat exposure for 120 min. The extract of *S. aromaticum* (bud) was relatively heat-labile compared with the other three herbal extracts, as its activity was reduced by almost 40% after heat exposure for 60–120 min. Similar tendency was also observed in the [•]OH-scavenging activity of the four herbal extracts exposed to heat (100°C).

Conclusion

These results indicate that the four herbal extracts chosen from extensive screening possess desirable antioxidant properties. In particular, the extracts of *P. granatum* (peel), *M. indica* (kernel) and *P. emblica* (fruit) are expected to be suitable for food processing in which thermal devices are used, because of their heat resistance.

Abbreviations

ESR	electron spin resonance
ROS	reactive oxygen species
HPX	hypoxanthine
XOD	xanthine oxidase
DMPO	5,5-dimethyl-1-pyrroline- <i>N</i> -oxide

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