

Screening of antioxidant activity and antioxidant compounds of some edible plants of Thailand

Anchana Chanwitheesuk, Aphiwat Teerawutgulrag, Nuansri Rakariyatham *

Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand

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Abstract

A large number of plants, which have been used as food and herbs in Thailand, were investigated for their antioxidant activity by using a β -carotene bleaching method. The contents of plant chemicals, such as vitamin C, vitamin E, carotenoids, tannin, and total phenolics, were also determined. The results showed that the highest antioxidant activity was found in the plant *Gymnema inodorum*, followed by *Piper sarmentosum* and *Mentha arvensis*, respectively. *G. inodorum* also contained the highest amount of vitamin E, and *M. arvensis* contained the highest amount of total xanthophylls. Correlations between the chemical content of each plant and the antioxidant index were observed. The results suggest that chemicals such as vitamin C, vitamin E, carotenoids, and phenolic compounds are the contributors to the antioxidant activity in the plants.

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1. Introduction

The oxidative deterioration of lipid-containing food is responsible for the rancid odours and flavours during processing and storage, consequently decreasing the nutritional quality and safety of foods due to the formation of secondary, potentially toxic compounds (Zainol, Abd-Hamid, Yusof, & Muse, 2003). Moreover, in humans, lipid oxidation is also thought to induce physiological obstruction, causing aging of the cells and carcinogenesis (Lampart-Szczapa, Korczak, Nogala-Kalucka, & Zawirska-Wojtasiak, 2003). A large number of experimental studies indicate that lipid oxidation products, called free radicals, can harm healthy cells, create harmful molecules, and contribute to the degenerative processes related to aging and diseases, e.g. cancer,

cardiovascular disease, and neurodegenerative disorders, such as Alzheimer's disease (Croft, 1999; Lemberkovic, Czinner, Szentmihályi, Balázs, & Szöke, 2002; Sami, 1995; Shon, Kim, & Sung, 2003). The antioxidants are now known to play an important role in protection against disorders caused by oxidant damage. The term "antioxidants" refers to compounds that can delay or inhibit the oxidation of lipids or other molecules by inhibiting the initiation or propagation of oxidative chain reaction (Velioglu, Mazza, Gao, & Oomah, 1998), and which can thus prevent or repair damage done to the body's cells by oxygen. They act in one or more of the following ways: reducing agents, free radical scavengers, potential complexers of pro-oxidant metals, and quenchers of singlet oxygen (Hudson, 1990).

Recently, there has been a considerable interest in finding natural antioxidants from plant materials to replace synthetic ones. Natural antioxidant substances are presumed to be safe since they occur in plant foods, and

* Corresponding author. Tel.: +66 53 943341-45x342; fax: +66 53 892277.

E-mail address: nuansril@yahoo.com (N. Rakariyatham).

are seen as more desirable than their synthetic counterparts. Data from both scientific reports and laboratory studies show that plants contain a large variety of substances called “plant chemicals” or “phytochemicals” that possess antioxidant activity (Pratt, 1992). Natural antioxidants occur in all higher plants, and in all parts of the plant (wood, bark, stems, pods, leaves, fruit, roots, flowers, pollen, and seeds). Typical compounds that exhibit antioxidant activity include vitamins, carotenoids, and phenolic compounds. Therefore, recommendations have been made to increase the daily intake of fruit and vegetables, which are rich in these nutrients that lower the risk of chronic health problems associated with the diseases mentioned above (Klipstein-Grobusch et al., 2000; Moeller, Jacques, & Blumberg, 2000; Morris et al., 1998; Slattery et al., 2000).

The antioxidant compounds of higher plants have been demonstrated, *in vitro* experiments, to protect against oxidation damage by inhibiting or quenching free radicals and reactive oxygen species. The roles of these compounds as potential antioxidants can be inferred by their similarity to synthetic antioxidants, of related structures (Larson, 1988). Vitamin C has been proposed, for a long time, as a biological antioxidant. It was found to act as a chain-breaking scavenger for peroxy radicals and also to act as a synergist with vitamin E, since vitamin C can donate a hydrogen atom to the vitamin E-derived phenolate radical, thus regenerating its activity. Vitamin E is one of the best quenchers for singlet oxygen, and can act as a chain-breaking antioxidant. Furthermore, singlet oxygen is very powerfully quenched by carotenoids, especially β -carotene. In the case of phenolic compounds, the ability of the phenolics to act as antioxidants depends on the redox properties of their phenolic hydroxyl groups, that allow them to act as reducing agents, hydrogen-donating antioxidants, oxygen quenchers (Rice-Evans & Miller, 1996).

In the present study, we collected 43 edible plant species from eight families that are widely consumed in Thailand, and analyzed antioxidant activities of methanolic extracts prepared from these plants. The contents of six antioxidant compounds, including vitamin C, vitamin E, total carotenes, total xanthophylls, tannins, and total phenolics, were also investigated in the plants.

2. Materials and methods

2.1. Plant material

The plant species used were purchased from a local market in Chiang Mai, Thailand, during June–October 2000. They were identified botanically at the Biology Department of Chiang Mai University. The scientific names of the plants which were used in the study are given in Table 1. The plants were cleaned and cut into

small pieces before being dried in a hot air-blowing oven at 50 °C. All samples, after drying, had water contents below 10%. They were ground to a fine powder in a mechanical blender and kept at room temperature prior to extraction. The dried plants were used for the analysis of antioxidant activity, vitamin C, vitamin E, carotenoids, tannins and phenolic compounds.

2.2. Determination of antioxidant activity

A dried plant was soaked overnight in methanol at room temperature in a flask. Each flask contained 0.5 g sample in 10 ml of methanol. The extract was filtered through Whatman No. 42 filter paper, and the residue was washed with hot methanol. The insoluble residue was discarded. The filtrate was evaporated in a water bath at 40 °C to a final volume 1 ml. Antioxidant activity was determined by measuring the coupled oxidation of carotene and linoleic acid, as described by Hammerschmidt and Pratt (1978). One ml of β -carotene solution in chloroform (1 mg/10 ml) was pipetted into a flask, which contained linoleic acid and Tween 40. After removal of the chloroform on a water bath at 50 °C, 50 ml of distilled water (which was bubbled by an air pump for 1 h) were added to the flask with vigorous swirling. Five ml aliquots of this emulsion were placed in test tubes which contained 0.2 ml of the extracts. Samples were read against a blank containing the emulsion minus the carotene. A reading at 470 nm was taken immediately ($t = 0$) and then at 15-min intervals for 105 min. The bleaching rate of β -carotene was determined by the difference in the spectral absorbance reading between the initial and last reading of bleaching that remained essentially linear divided by time. The antioxidant index was the ratio of the bleaching rate of control (system with no added test compound) to the bleaching rate when a test compound was in the system.

2.3. Determination of vitamin C content

The content of vitamin C in the plants was determined by the spectrophotometric procedure of Bajaj and Kaur (1981). A known mass of dried plant material (0.5 g) was extracted overnight with 10 ml of oxalic acid–EDTA solution at room temperature. The extract was filtered through a filter paper. A 2.5 ml aliquot was then transferred into a 25-ml volumetric flask. Then, the other reagents (2.5 ml of oxalic acid–EDTA solution, 0.5 ml of metaphosphoric acid–acetic acid solution, 0.1 ml of sulfuric acid solution, and 2 ml of ammonium molybdate reagent) were added. After that, the solvent was adjusted to a volume of 25 ml with distilled water. The molybdenum blue complex, which was formed by the reduction of ammonium molybdate with ascorbic acid (vitamin C), was

Table 1
Edible plants used in this study

Scientific name	Common name	Part used	Uses
(Family Araliaceae)			
<i>Acanthopanax trifoliatum</i>	–	Leaves	–
<i>Macropanax dispermus</i>	–	Leaves	Digestive tonic
<i>Polycia fruticosa</i>	–	Leaves	Poultice for swelling, antipyretic
(Family Asclepiadaceae)			
<i>Dregea volubilis</i>	–	Leaves	Poultice for swelling
<i>Gymnema inodorum</i>	–	Leaves	Antihyperglycemia
<i>Marsdenia glabra</i>	–	Leaves	Digestive tonic, restorative, antipyretic
<i>Telosma minor</i>	Tonkin jasmine	Flowers	Restorative, detoxicant
(Family Cucurbitaceae)			
<i>Coccinia grandis</i>	Ivy gourd	Leaves	Antihyperglycemia
<i>Cucurbita moschata</i>	Pumpkin	Leaves	Carminative, expectorant
<i>Momordica charantia</i>	Bitter gourd	Fruit	Antihyperglycemia
<i>Sechium edule</i>	Chayote	Leaves	–
(Family Labiatae)			
<i>Coleus amboinicus</i>	Country borage	Leaves	Cure otorrhea, otitis
<i>Mentha arvensis</i>	Japanese mint	Leaves	Relieve headache, antipyretic
<i>M. cordifolia</i>	Kitchen mint	Leaves	Relieve headache, carminative
<i>Ocimum americanum</i>	Hairy basil	Leaves	Carminative, relieve cold
<i>O. basilicum</i>	Sweet basil	Leaves	Digestive tonic, carminative, expectorant, relieve headache
<i>O. gratissimum</i>	–	Leaves	Expectorant, carminative, relieve stomach ache and flatulence
<i>O. sanctum</i>	Holy basil	Leaves	Expectorant, carminative, relieve stomach ache and flatulence
<i>Orthosiphon grandiflorus</i>	Cat's whisker	Leaves	Uretic
(Family Leguminosae)			
<i>Acacia pennata</i>	Acacia leaf	Shoot tips	Carminative, relieve flatulence
<i>Bauhinia purpurea</i>	–	Leaves	Antitussive, uretic
<i>Caesalpinia mimosoides</i>	–	Shoot tips	Digestive tonic
<i>Cassia siamea</i>	Thai copper pod	Leaves	Laxative, haemagogic, uretic
<i>Leucaena leucocephala</i>	Lead tree	Shoot tips	Relieve diarrhea
<i>Neptunia oleracea</i>	Water cress	Leaves	Detoxicant
<i>Pueraria mirifica</i>	–	Stem	Restorative
<i>Tamarindus indica</i>	Tamarind	Shoot tips	Antitussive, expectorant
(Family Piperaceae)			
<i>Piper retrofractum</i>	Long pepper	Flower	Antidiarrheic, carminative
<i>P. sarmentosum</i>	–	Leaves	Digestive tonic, carminative, expectorant, antihyperglycemia, antimalaria
(Family Umbelliferae)			
<i>Anethum graveolens</i>	Dill	Seed	Restorative, carminative, expectorant, relieve nausea
<i>Apium graveolens</i>	–	Leaves	Restorative, carminative, uretic
<i>Centella asiatica</i>	Pennywort	Leaves	Poultice for wound, scar or ulcer
<i>Coriandrum sativum</i>	Coriander	Leaves	Carminative, relieve flatulence, antipyretic, antitussive
<i>Eryngium foetidum</i>	False coriander	Leaves	Digestive tonic, carminative, relieve flatulence
<i>Oenanthe stolonifera</i>	Chinese celery	Leaves	Digestive tonic, expectorant, relieve flatulence,
(Family Zingiberaceae)			
<i>Amomum krevanh</i>	Siam cardamom	Fruit	Carminative, relieve flatulence
<i>Boesenbergia pandurata</i>	Wild ginger	Rootstock	Restorative, carminative, relieve flatulence, uretic, haemagogic
<i>Curcuma xanthorrhiza</i>	–	Rootstock	Relieve stomachache
<i>Kaempferia galanga</i>	–	Rootstock	Carminative, relieve flatulence, haemagogic
<i>Languas galanga</i>	Greater galanga	Rootstock	Carminative, relieve flatulence
<i>Zingiber cassumunar</i>	–	Rootstock	Carminative, haemagogic, relieve muscle pain and beriberi
<i>Z. officinale</i>	Ginger	Rootstock	Restorative, carminative, relieve flatulence
<i>Z. zerumbet</i>	Zerumbet ginger	Rootstock	Restorative, carminative, uretic, expectorant

measured for absorbance after 15 min at 760 nm. The content of vitamin C was then determined by referring to the calibration graph, using ascorbic acid solution as a standard solution.

2.4. Determination of vitamin E content

Dried plant material (0.5 g) was immersed in 20 ml of ethanol for 30 min in a water bath at 85 °C. The solution

was allowed to cool and then filtered into a separating funnel. Heptane (10 ml) was added, and the solution was shaken for 5 min. Then, 20 ml of 1.25% sodium sulfate was added and the solution was shaken again for 2 min, and allowed to separate into layers. Total tocopherols were determined by a reaction with cupric ions and complexation with 2,2'-biquinoline (cuproine) according to Contreras-Guzmán and Strong (1982). A volume of 0.5 ml of α -tocopherols in ethanol was processed in the same way as a sample, and used as a standard.

2.5. Determination of carotenoids content

Dried plant material (0.5 g) was extracted with 30 ml of hexane at room temperature, with hot saponification, as described by Helrich (1990). The isolation of carotenes and xanthophylls in the extract of dried samples was performed by column chromatography. For this condition, Hyflo Super-Cel was used as a stationary phase, and solutions, of hexane–acetone (9:1 v/v) and hexane–acetone–methanol (8:1:1 v/v/v) were used as a mobile phase for the separation of carotenes and xanthophylls, respectively. The content of carotenes and xanthophylls was determined by measuring absorbance at 436 and 474 nm, respectively.

2.6. Determination of tannins content

Dried plant material (0.5 g) was extracted with 300 ml of diethyl ether for 20 h at room temperature. The residue was boiled for 2 h with 100 ml of distilled water, and then allowed to cool, and was filtered. The extract was adjusted to a volume of 100 ml in a volumetric flask. The content of tannins in the extract was determined colorimetrically using Folin–Denis reagent, and by measuring absorbance of the blue complex at 760 nm, using tannic acid solution as a standard solution, as described by Helrich (1990).

2.7. Determination of total phenolics content

The extraction of total phenolics was performed according to Naczki, Wanasundara, and Shahidi (1992) with a slight modification. One gramme of dried plant material was extracted three times with 20 ml of acetone–methanol–water (7:7:6 v/v/v) at room temperature. The extract was centrifuged at 6000 rpm for 10 min. After centrifugation, the combined supernatant was analyzed for total phenolics according to Hammerschmidt and Pratt (1978) with some modifications. The procedure consisted of combining 1 ml of test solution with 10 ml of deionized water and 2 ml of Folin–Denis reagent. After 5 min, 2 ml of saturated sodium carbonate solution were added, and the mixture was incubated for 1 h at room temperature. Absorbance was then measured at 640 nm. Pyrocatechol solution was used

as a standard for the determination of total phenolics content.

2.8. Statistical analysis

Mean values and standard deviations (S.D.) were calculated from the results. One way analysis of variance (ANOVA) was applied for comparison of the mean values. P value < 0.05 was regarded as significant. Correlation coefficients (R), to determine the relationship between two variables (between antioxidant index and content of antioxidant compounds in the plants), were also calculated by using the Statistical Package for Social Science (SPSS) programme.

3. Results and discussion

The antioxidant activity of plants is mainly contributed by the active compounds present in them. In this study, the antioxidant activity and the content of active compounds of 43 edible plants belonging to eight families were determined. The results are summarized in Table 2. It was found that the methanolic extracts of all plants showed antioxidant activity. Stronger activity is indicated by a higher antioxidant index. Significant differences ($P < 0.05$) were found in the antioxidant indices of the tested plants. The methanolic extract of the leaves of *Gymnema inodorum* exhibited the highest level of antioxidant activity with the index of 14.8, followed by *Piper sarmentosum* (13) and *Mentha arvensis* (10.9), respectively. The plants *G. inodorum* and *P. sarmentosum* are native herbs in Southeast Asia. They are used as food and traditional medicine in Thailand. The leaves of *G. inodorum* have been known to be effective for some diseases, including diabetes mellitus, rheumatic arthritis, and gout. A few studies on pharmacological activities of the *G. inodorum* extract have been scientifically investigated. It has been reported that the extract of *G. inodorum* inhibits the increase in blood sugar level by interfering with the intestinal glucose absorption process (Shimizu et al., 2001; Shimizu et al., 1997). The plant *P. sarmentosum* is one of the medicinal plants which possess antimalarial activity (Rahman, Furuta, Kojima, Takane, & Mohd, 1999), and neuromuscular blocking activity (Ridititid, Rattanaprom, Thaina, Chittrakarn, & Sunbhanich, 1998). The water decoction of the whole plant of this species has also been traditionally used to treat diabetic patients. It has been reported that the aqueous extract of *P. sarmentosum* has a hypoglycemic effect in rats (Peungvicha et al., 1998). Antibacterial and antifungal activities have been investigated in the plant *M. arvensis* (Imai et al., 2001; Kishore, Mishra, & Chansouria, 1993). The result of this study suggests that the three plants can be used as a potential source of natural antioxidants, with their pharmaceutical applications.

Table 2
Antioxidant index and content of antioxidant compounds of the tested plants (\pm standard deviation)

Plants	Antioxidant index	Antioxidant compound content (mg%)					
		Vitamin C	Vitamin E	Total carotenes	Total xanthophylls	Tannins	Total phenolics
Araliaceae							
<i>A. trifoliatum</i>	4.37 \pm 0.17	15.3 \pm 0.07	0.0055 \pm 0.0002	2.54 \pm 0.03	3.17 \pm 0.04	57.3 \pm 0.10	275 \pm 0.11
<i>M. dispermus</i>	1.27 \pm 0.10	31.0 \pm 0.07	0.0064 \pm 0.0004	3.89 \pm 0.06	1.06 \pm 0.04	37.4 \pm 0.11	651 \pm 0.10
<i>P. fruticosa</i>	2.92 \pm 0.12	9.11 \pm 0.08	0.0201 \pm 0.0015	2.52 \pm 0.07	2.13 \pm 0.03	24.3 \pm 0.12	46.3 \pm 0.09
Asclepiadaceae							
<i>D. volubilis</i>	7.20 \pm 0.85	20.0 \pm 0.08	0.0015 \pm 0.0002	6.14 \pm 0.07	1.07 \pm 0.03	17.7 \pm 0.08	100 \pm 0.09
<i>G. inodorum</i>	14.8 \pm 0.98	19.3 \pm 0.08	0.0301 \pm 0.0011	1.31 \pm 0.03	1.07 \pm 0.03	11.1 \pm 0.11	188 \pm 0.12
<i>M. glabra</i>	2.06 \pm 0.63	22.7 \pm 0.06	0.0018 \pm 0.0005	8.92 \pm 0.04	7.42 \pm 0.04	4.47 \pm 0.07	51.5 \pm 0.10
<i>T. minor</i>	2.85 \pm 0.39	23.6 \pm 0.05	0.0070 \pm 0.0011	1.29 \pm 0.04	4.24 \pm 0.03	17.7 \pm 0.09	98.4 \pm 0.11
Cucurbitaceae							
<i>C. grandis</i>	2.87 \pm 0.05	16.6 \pm 0.07	0.0070 \pm 0.0013	1.94 \pm 0.03	2.65 \pm 0.04	17.7 \pm 0.10	74.7 \pm 0.10
<i>C. moschata</i>	0.91 \pm 0.03	27.8 \pm 0.06	0.0045 \pm 0.0007	1.92 \pm 0.04	1.59 \pm 0.05	4.48 \pm 0.06	87.8 \pm 0.12
<i>M. charantia</i>	1.49 \pm 0.18	13.8 \pm 0.06	0.0024 \pm 0.0005	1.31 \pm 0.07	0.54 \pm 0.04	4.48 \pm 0.05	37.0 \pm 0.13
<i>S. edule</i>	4.89 \pm 0.68	17.9 \pm 0.06	0.0197 \pm 0.0010	3.83 \pm 0.04	2.13 \pm 0.03	4.48 \pm 0.08	66.1 \pm 0.14
Labiatae							
<i>C. amboinicus</i>	4.22 \pm 0.43	10.2 \pm 0.05	0.0054 \pm 0.0011	2.54 \pm 0.05	4.24 \pm 0.03	24.3 \pm 0.09	54.8 \pm 0.11
<i>M. arvensis</i>	10.9 \pm 0.55	12.8 \pm 0.08	0.0294 \pm 0.0015	4.48 \pm 0.06	26.5 \pm 0.03	21.0 \pm 0.9	70.0 \pm 0.13
<i>M. cordifolia</i>	7.45 \pm 0.53	11.3 \pm 0.05	0.0016 \pm 0.0007	2.58 \pm 0.06	4.24 \pm 0.03	73.7 \pm 0.10	280 \pm 0.14
<i>O. americanum</i>	3.67 \pm 0.24	5.48 \pm 0.05	0.0040 \pm 0.0010	5.12 \pm 0.04	9.52 \pm 0.03	11.1 \pm 0.06	43.6 \pm 0.04
<i>O. basilicum</i>	5.12 \pm 0.45	6.79 \pm 0.05	0.0101 \pm 0.0012	10.8 \pm 0.06	13.3 \pm 0.05	30.9 \pm 0.10	83.3 \pm 0.09
<i>O. gratissimum</i>	10.8 \pm 0.79	5.09 \pm 0.06	0.0206 \pm 0.0018	2.56 \pm 0.09	7.94 \pm 0.03	24.3 \pm 0.08	125 \pm 0.11
<i>O. sanctum</i>	4.23 \pm 0.21	9.23 \pm 0.07	0.0202 \pm 0.0014	5.13 \pm 0.04	3.18 \pm 0.04	40.8 \pm 0.10	91.8 \pm 0.12
<i>O. grandiflorus</i>	1.99 \pm 0.32	7.69 \pm 0.07	0.0011 \pm 0.0004	3.20 \pm 0.06	25.4 \pm 0.02	30.9 \pm 0.11	145 \pm 0.12
Leguminosae							
<i>A. pennata</i>	1.46 \pm 0.27	22.3 \pm 0.08	0.0015 \pm 0.0005	1.27 \pm 0.05	1.59 \pm 0.04	11.1 \pm 0.09	121 \pm 0.09
<i>B. purpurea</i>	3.73 \pm 0.52	13.9 \pm 0.05	0.0103 \pm 0.0011	2.55 \pm 0.07	3.72 \pm 0.04	24.3 \pm 0.07	59.5 \pm 0.13
<i>C. mimosoides</i>	5.43 \pm 0.61	20.1 \pm 0.07	0.0105 \pm 0.0009	1.92 \pm 0.05	5.28 \pm 0.04	484 \pm 0.13	1924 \pm 0.31
<i>C. siamea</i>	1.92 \pm 0.50	48.4 \pm 0.16	0.0204 \pm 0.0014	1.92 \pm 0.05	1.59 \pm 0.06	110 \pm 0.10	384 \pm 0.11
<i>L. leucocephala</i>	9.37 \pm 0.50	48.5 \pm 0.13	0.0202 \pm 0.0006	0.64 \pm 0.05	3.18 \pm 0.03	60.6 \pm 0.11	405 \pm 0.18
<i>N. oleracea</i>	1.16 \pm 0.07	12.9 \pm 0.07	0.0066 \pm 0.0005	3.18 \pm 0.08	1.06 \pm 0.02	21.0 \pm 0.10	104 \pm 0.14
<i>P. mirifica</i>	6.54 \pm 0.72	5.63 \pm 0.08	0.0011 \pm 0.0002	0.63 \pm 0.03	0.52 \pm 0.04	1.18 \pm 0.05	15.8 \pm 0.10
<i>T. indica</i>	1.10 \pm 0.12	4.96 \pm 0.04	0.0015 \pm 0.0005	0.64 \pm 0.04	1.05 \pm 0.04	77.0 \pm 0.08	121 \pm 0.04
Piperaceae							
<i>P. retrofractum</i>	3.36 \pm 0.45	9.37 \pm 0.04	0.0053 \pm 0.0009	1.28 \pm 0.05	5.31 \pm 0.03	7.78 \pm 0.06	57.5 \pm 0.12
<i>P. sarmentosum</i>	13.0 \pm 0.84	16.6 \pm 0.06	0.0100 \pm 0.0006	3.82 \pm 0.06	5.81 \pm 0.04	17.7 \pm 0.06	123 \pm 0.12
Umbelliferae							
<i>An. graveolens</i>	1.09 \pm 0.21	11.7 \pm 0.07	0.0039 \pm 0.0002	0.64 \pm 0.03	0.53 \pm 0.02	7.78 \pm 0.06	66.1 \pm 0.15
<i>Ap. graveolens</i>	6.39 \pm 0.67	6.65 \pm 0.07	0.0070 \pm 0.0012	1.28 \pm 0.05	3.72 \pm 0.05	4.49 \pm 0.07	31.1 \pm 0.14
<i>C. asiatica</i>	7.10 \pm 0.62	3.28 \pm 0.05	0.0031 \pm 0.0005	12.8 \pm 0.04	10.6 \pm 0.04	24.3 \pm 0.06	98.5 \pm 0.10
<i>C. sativum</i>	1.41 \pm 0.11	11.0 \pm 0.06	0.0038 \pm 0.0006	2.52 \pm 0.03	1.05 \pm 0.05	24.3 \pm 0.08	33.0 \pm 0.14
<i>E. foetidum</i>	5.65 \pm 0.46	11.4 \pm 0.07	0.0069 \pm 0.0007	1.92 \pm 0.03	1.60 \pm 0.05	17.7 \pm 0.08	98.4 \pm 0.08
<i>O. stolonifera</i>	7.92 \pm 0.93	9.11 \pm 0.07	0.0051 \pm 0.0009	3.83 \pm 0.05	14.8 \pm 0.06	34.2 \pm 0.09	329 \pm 0.19
Zingiberaceae							
<i>A. krervanh</i>	4.00 \pm 0.72	2.52 \pm 0.05	0.0043 \pm 0.0006	1.29 \pm 0.04	1.07 \pm 0.03	7.77 \pm 0.09	46.3 \pm 0.13
<i>B. pandurata</i>	0.91 \pm 0.16	0.98 \pm 0.03	0.0032 \pm 0.0004	0.64 \pm 0.03	0.52 \pm 0.03	4.48 \pm 0.07	20.5 \pm 0.08
<i>C. xanthorrhiza</i>	0.69 \pm 0.08	7.69 \pm 0.05	0.0085 \pm 0.0006	1.28 \pm 0.04	0.65 \pm 0.03	14.4 \pm 0.08	112 \pm 0.13
<i>K. galanga</i>	3.15 \pm 0.22	5.37 \pm 0.04	0.0035 \pm 0.0005	1.91 \pm 0.02	1.59 \pm 0.02	4.48 \pm 0.09	26.4 \pm 0.11
<i>L. galanga</i>	3.24 \pm 0.53	7.87 \pm 0.05	0.0042 \pm 0.0011	0.64 \pm 0.02	1.05 \pm 0.04	17.7 \pm 0.05	63.4 \pm 0.10
<i>Z. cassumunar</i>	10.9 \pm 0.84	13.4 \pm 0.04	0.0065 \pm 0.0009	1.27 \pm 0.04	0.54 \pm 0.04	1.18 \pm 0.07	83.9 \pm 0.13
<i>Z. officinale</i>	2.00 \pm 0.75	9.38 \pm 0.03	0.0039 \pm 0.0006	0.64 \pm 0.04	1.06 \pm 0.03	11.1 \pm 0.10	60.1 \pm 0.14
<i>Z. zerumbet</i>	3.00 \pm 0.61	5.87 \pm 0.05	0.0209 \pm 0.0012	1.29 \pm 0.07	4.23 \pm 0.04	17.7 \pm 0.08	79.3 \pm 0.13

Typical compounds that possess antioxidant activity have been characterized as vitamin C, vitamin E, carotenoids and phenolic compounds. It was reasonable to investigate their total level in the tested plants. Signifi-

cant differences ($P < 0.05$) were found in all of these amounts. The content of vitamin C of the plants varied from 0.98 to 48.5 mg%. The highest amount was found in the extract of *Leucaena leucocephala*. A high content

of vitamin C was also present in *Cassia siamea* and *Macropanax dispermus*. Correlation between the vitamin C content and the antioxidant index was only found in plants of the families Piperaceae ($R = 0.99$) and Zingiberaceae ($R = 0.63$). The content of vitamin E (mg%) ranged from 0.0011 to 0.0301. The highest amounts were found in the extracts of *G. inodorum* and *M. arvensis*. A correlation between the content of vitamin E and the antioxidant index was observed in several families (Asclepiadaceae, $R = 0.87$; Cucurbitaceae, $R = 0.90$; Labiatae, $R = 0.69$; Leguminosae, $R = 0.39$; and Piperaceae, $R = 0.96$), indicating that vitamin E was likely to contribute to the antioxidant activity of these plants.

Regarding the content of carotenoids (mg%), total carotenes varied from 0.63 to 12.8, and total xanthophylls varied from 0.52 to 26.5. The lowest amount of both carotenoids was found in *Pueraria mirifica*, while *Centella asiatica* and *M. arvensis* contained the highest amounts of total carotenes and total xanthophylls, respectively. In this study, a correlation between the content of total carotenes and the antioxidant index was found in Cucurbitaceae ($R = 0.87$), Piperaceae ($R = 0.99$) and Umbelliferae ($R = 0.46$). However, it can be observed that the amount of total xanthophylls in the plants showed a correlation with the antioxidant index in many families (Araliaceae, $R = 0.98$; Cucurbitaceae, $R = 0.56$; Leguminosae, $R = 0.41$; Piperaceae, $R = 0.98$; Umbelliferae, $R = 0.77$).

Among phenolic compounds (mg%), tannins ranged from 1.18 to 484, and total phenolics from 15.8 to 1924. The plant *Caesalpinia mimosoides* exhibited the highest amount of both tannins and total phenolics, while the lowest amounts of both compounds were observed in the extract of *P. mirifica*. A correlation between the content of tannins and the antioxidant index was only found in the Araliaceae and Piperaceae families ($R = 0.72$ and 0.99 , respectively). A correlation between the content of total phenolics and the antioxidant index was found in some families (Asclepiadaceae, $R = 0.94$; Piperaceae, $R = 0.99$; Umbelliferae, $R = 0.57$).

From Table 2, by employing correlation coefficients, it was revealed that vitamin E and total xanthophylls had a relationship with the antioxidant index in five of eight families tested in this study. However, vitamin C, total carotenes, tannins, and total phenolics also showed a relationship with antioxidant index in some families.

Several comprehensive reviews of the literature on natural antioxidants have recently appeared. Many published data highlight the potential role of the phenolic components of fruit, vegetables, beverages, and grain, which may act as antioxidants (Ancos, González, & Pilar Cano, 2000; Miliauskas, Venskutonis, & van Beek, 2004; Miranda et al., 2000; Zainol et al., 2003; Zielinski & Kozłowska, 2000). However, the results in this study

demonstrated that the plants which contained a high amount of vitamins or carotenoids, also possessed a high level of antioxidant activity. These results are in agreement with those in previously published literature. Larson (1988) reported the roles of many other compounds as potential antioxidants of higher plants (e.g. vitamins C and E, carotenoids, chlorophyll derivatives, alkaloids, flavonoids, phenolic acids and other phenol). A similar finding was reported by Rice-Evans and Miller (1996), who determined the relative antioxidant potentials of vitamins, carotenoids, and phenolics in many kinds of fruit and vegetables. Javanmardi, Stushnoff, Locke, and Vivanco (2003) also found that the antioxidant activity of plant extracts is not limited to phenolics. The activity may also come from the other antioxidant secondary metabolites, such as volatile oils, carotenoids and vitamins.

4. Conclusions

The study shows that there are differences in the contents of antioxidant compounds of the plants commonly consumed in Thailand. Some of the plants can be considered as good sources of natural antioxidants since their extracts were found to possess high antioxidant activity. The highest activity was detected in *G. inodorum*, followed by *P. sarmentosum* and *M. arvensis*, respectively. Inspection reveals that contents of vitamin C, vitamin E, total carotenes, total xanthophylls, tannins and total phenolics in the test plants correlated with the antioxidant index. The results suggest that the antioxidant activities of these plants may be attributed to the chemical components present, especially vitamin E and xanthophylls.

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