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Antioxidant activities and phenolic content of *Solanum* and *Capsicum* sp.

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ABSTRACT

Fourteen *Solanum* cultivars (*S. aculeatissimum*, *S. melongena*, *S. torvum*, *S. trilobatum*, *S. stramonifolium*, *S. mammosum* and *S. wrightii*) and fourteen *Capsicum* cultivars (*C. annuum*, *C. frutescens* and *C. minimum*) cultivated in Thailand were determined their total phenolic contents in term of gallic acid (g) per 100 g of crude extract and per 100 g of dry herb powder. The total phenolic content of *Solanum* sp. were in range of 1.55-4.39 g/100 g of crude extract and 0.34-1.13 g/100 g of dry herb powder and of *Capsicum* sp. were in range of 2.02-3.28 g/100 g of crude extract and 0.49-1.02 g/ 100 g of dry herb powder. The antioxidant activities were measured by Trolox Equivalent Capacity Assay (TEAC). The TEAC values of *Solanum* sp. were in range of 0.01 - 0.03 and of *Capsicum* sp. were 0.01 - 0.02. The antioxidant activities of *Solanum* and *Capsicum* sp. presented linear relationship to their total phenolic contents, which indicated that 50.48% and 0.07% of antioxidant activities of *Solanum* and *Capsicum* sp. came from their total phenols, respectively.

Keywords: *Solanum* sp., *Capsicum* sp., total phenolic contents, antioxidant activities, TEAC

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INTRODUCTION

The solanum and capsicum are edible vegetable in family Solanaceae. They are cultivated worldwide. They are appreciated ingredients in food with high nutritional values and biological activities. The solanum and capsicum contain many secondary metabolites. For example, *S. torvum* contains 2,3,4-trimethyltriacontane, octacosanyl triacontanoate, 5-hexatriacontanone, triacontanol, 3-tritriacontanone, tetratriacontanoic acid, sitosterol, stigmasterol, campesterol [1], solanolactosides A and B, torvosides M and N [2], torvosides A-G [3], Torvonin-A [4], chlorogenone, neochlorogenone [5]; *S. aculeatissimum* contains steroidal glycosides, aculeatiside A and B [6], solasodine [7]; *S. melongena* contains solasodine [7], melongoside L, melongoside M [8], Melongosides N, O and P [9], 24-(R)-ethyllophenol [10] *S. trilobatum* contains β -sitosterol [11]. The capsicum contains phenolic acid, flavonoids [12], carotenoid [13] capsaicinoids (capsaicin, dihydrocapsaicin, homocapsaicin I, homocapsaicin II, norcapsaicin, nornorcapsaicin, homodihydrocapsaicin I, homodihydrocapsaicin II, nordihydrocapsaicin, nornordihydrocapsaicin) [14], steroids [15] (lanosterol, lanostenol) and steroidal glycosides (capsicosides A–D, proto-degalactotigonin) [16]. The solanum presented physiological activities to human and animals as reduced systolic blood pressure [17-18] hypoglycemia [19], antiulcer [20], antiviral [21], antioxidant [22], bronchospasmogenic [23], analgesic, CNS depression [24], hepatoprotective [25], antitumor [26-27] and cytotoxic [2, 28] effects. The capsicum exhibits antimicrobial effect [29-30], enhance interleukin-2 and interferon-gamma production in cultured cells *ex vivo* [31] and chemopreventive properties [32]. The capsaicinoids in capsicum are used as analgesic and anti-inflammatory [33] in pharmaceutical products. The capsaicinoids also have flavoring and aroma properties that are used in food industries.

The dietary antioxidants from fruits and vegetables are suggested to protect cells from oxidative stress damage [34], and the *S. melongena* pulp is widely studied its total phenolic contents and *in vitro* free radical scavenging activities [35-38]. The *S. torvum* seed protein shows good activity for scavenging DPPH radicals [39]. The methanolic extract of *S. trilobatum* plant presents antioxidant activity against *N*-diethylnitrosamine (DEN) induced hepatocarcinogenesis [40]. For *C. annuum* [41-44] and *C. frutescens* [45], their total phenolic contents and antioxidant activities of fruits have measured previously. Although the total phenols and antioxidant activities of many solanum and capsicum are measured, the fruit of various kind of solanum and capsicum cultivars in Thailand have not been investigated. The aim of this study was to determine the total phenolic contents and antioxidant activities of various cultivars of solanum and capsicum fruit cultivated in Thailand by TEAC method.

MATERIALS AND METHODS

Plants

The local *Solanum* sp. (*S. aculeatissimum*, *S. melongena*, *S. torvum*, *S. trilobatum*, *S. stramonifolium*, *S. mammosum* and *S. wrightii*) and *Capsicum* sp. (*C. annuum*, *C. frutescens* and *C. minimum*.) was purchased from local fresh markets in Nakhon-Pathom province, Thailand in

October 2009. The voucher specimens (Makhuea001-Makhuea014 and Prick001-Prick014) were deposited in the Department of Pharmacognosy, Silpakorn University in Nakhon-Pathom, Thailand.

Chemicals

ABTS²⁻, 2,2'-azinobis-(3-ethylbenzthiazoline-6-sulfo-nate), was obtained as sulfonic acid from Sigma (St. Louis, USA). Trolox (or (+/-)-6-hydroxy-2,5,7,8-tetra-methyl-chroman-2-carboxylic acid) was purchased from Aldrich (Steinheim, Germany). Potassium persulfate (FeSO₄x7H₂O) and sodium acetate were obtained from Asia Pacific Specialty Chemicals Limited (Seven Hills, Australia). Folin-Ciocalteu reagent, FeCl₃ x 6H₂O and NaCl were purchased from Carlo ErbaReagenti (Milano, Italy). 2,4,6-tri-pyridyl-s-triazine (TPTZ) was obtained from Fluka Chemie GmbH (Switzerland) and methanol was purchased from Merck (Darmstadt, Germany).

Methods

***Solanum* and *capsicum* extracts preparation.**

All type of solanum and capsicum fruits were cut and dried in hot air oven at 55°C for 72 h. After dried, they were milled to power and macerated with methanol, ratio of plant powder to methanol was 1:4 for 72 h then filtered. The filtrate was evaporated under vacuum (Buechi R205, Switzerland). The dried extracts were kept in refrigerator at 4°C until tested.

Quantitative of total phenols [46]

The 0.5 mL methanolic extract (10 µg/mL) of solanum or capsicum was mixed with 0.5 mL Folin-Ciocalteu reagent and 0.5 mL 10% Na₂CO₃ solution. The mixtures were placed at room temperature for 1 h. After incubation, the mixtures were measured absorbance at 760 nm using UV-Vis-Spectrophotometer, (Agilent 8453E UV-Visible Spectroscopy System, Agilent Technology, USA.). The calibration curve was prepared using gallic acid in concentration range 2-8 mg/L as standard. The total phenolic content was calculated and reported as gallic acid equivalent (GEA, g of gallic acid in 100g of methanolic extracts and of dried fruits).

Determination of antioxidant activities [47]

An antioxidant activity was determined by scavenging effect of ABTS⁺ radical or TEAC assay. The ABTS⁺ solution was prepared by mixing 7 mM ABTS²⁻ in water with 4.9 mM potassium persulfate in water (1:1). The solution was kept in dark chamber and at room temperature for 12–16 hrs. The absorbance (A) of ABTS⁺ was equilibrated to 0.7 (±0.02) at 734 nm using UV-Vis-Spectrophotometer by diluting with water.

All solanum and capsicum samples were prepared in concentration range of 100-500 µg/50µL. A 50 µL of sample was mixed with 3 mL of ABTS⁺ solution. After mixing, the mixture

had been allowed to stand at room temperature for 6 minutes. Its absorbance was measured at 734 nm by spectrophotometer. Trolox was used as a standard for preparing calibration curve. All antioxidant capacity measurements were calculated from average of quadruplicate absorbances. The antioxidant capacity of each sample was calculated for %inhibition and reported as concentration of sample that resulted 50% of inhibition (IC₅₀) and as trolox equivalent antioxidant capacity (TEAC).

Calculation of antioxidant capacity

The absorbance of sample (or trolox), A_(compound), and of solvent, A_(solvent), was used for %inhibition calculation as following equation.

$$\% \text{ inhibition} = \frac{A(\text{solvent}) - A(\text{compound})}{A(\text{solvent})} \times 100$$

The relationship of %inhibition and concentration of sample (or trolox) was plotted. The regression coefficient (r²) of linear curve was calculated. The IC₅₀ of sample was determined. The TEAC value was the ratio of %inhibition of sample to %inhibition of trolox at equal concentration.

RESULTS AND DISCUSSION

The total phenolic contents of *Solanum* sp. were rather low, Table 1. They were in range of 4.39-1.55 g as gallic acid /100g crude extract and 1.12-0.33 g as gallic acid /100g dried fruit. For *Solanum* crude extracts, the consequence of total phenolics from high to low were *S. melongena* (Long Purple Eggplant), *S. wrightii*, *S. aculeatissimum*, *S. trilobatum*, *S. mammosum*, *S. torvum*, and *S. stramonifolium*, respectively. For *solanum* dried fruits the consequence of total phenolics from high to low were *S. wrightii*, *S. trilobatum*, *S. melongena*, *S. mammosum*, *S. aculeatissimum*, *S. stramonifolium* and *S. torvum*, respectively. In this study, the amount of total phenolic contents of *S. melongena* were in range of 600-810 mg as gallic acid /100g dried-fruit which were higher than that of previous report of four different varieties of *S. melongena* cultivated in India (in range 49.02-106.98 mg as gallic acid /100g sample) [22]. The *Capsicum* sp. also showed low total phenolic contents. They were in range of 3.99-2.02 g as gallic acid /100g crude extract and 1.02-0.49 g as gallic acid /100g dried fruit. For *capsicum* crude extracts and dried fruits, the consequence of total phenolics from high to low were *C. frutescens*, *C. annum* and *C. minimum*, respectively.

The ABTS^{•-} radical is widely used to proof the antioxidant capacity of samples. The free radical scavenging ability of this investigated *Solanum* and *Capsicum* sp. extracts presented good linear relationship between antioxidant activities and concentrations.

Table 1 Total phenolic contents of solanum and capsicum fruits and extracts calculated as g of gallic acid.

Solanum and capsicum extracts	Total-Phenols (g/100g crude extract as Gallic acid)		Total-Phenols (g/100g dried-fruit as Gallic acid)	
	average	SD	average	SD
Solanum sp.				
<i>S. aculeatissimum</i> Jacq. (Brinjal)	2.54	0.01	0.59	0.00
<i>S. aculeatissimum</i> Jacq. (Ma Khuea Lueang)	3.52	0.01	0.37	0.00
<i>S. aculeatissimum</i> Jacq. (Ma Khuea Torae)	2.48	0.10	0.34	0.01
<i>S. aculeatissimum</i> Jacq. (Ma Khuea Bualoy)	3.66	0.06	0.56	0.01
<i>S. aculeatissimum</i> (Ma Khuea Lai)	2.05	0.26	0.60	0.08
<i>S. aculeatissimum</i> (Ma Khuea Laiyai)	1.92	0.07	0.65	0.03
<i>S. torvum</i> Sw. (Ma Khuea Phuang)	2.33	0.02	0.42	0.00
<i>S. melongena</i> L (Round Purple Eggplant)	3.22	0.11	0.77	0.03
<i>S. melongena</i> L. var. <i>serpentinum</i> (Desf.) Bailey (Long Purple Eggplant)	4.39	0.06	0.81	0.01
<i>S. melongena</i> L. var. <i>serpentinum</i> (Desf.) Bailey (Long Eggplant)	2.37	0.09	0.60	0.02
<i>S. mammosum</i>	3.08	0.09	0.75	0.02
<i>S. wrightii</i> Benth)Potato Tree(4.07	0.34	1.13	0.09
<i>S. stramonifolium</i> Jacq	1.55	0.05	0.48	0.01
<i>S. trilobatum</i> L.	3.25	0.32	0.98	0.10
Capsicum sp.				
<i>C. annum</i> L.var.grossum (Red Chili)	2.59	0.12	0.68	0.03
<i>C. annum</i> L. var. <i>acuminatum</i> Fingerh. (Yellow Chili)	2.30	0.03	0.64	0.01
<i>C. annum</i> L. var. <i>acuminatum</i> Fingerh (Chili Spur Pepper (Red))	2.02	0.01	0.49	0.00
<i>C. annum</i> L. var. <i>acuminatum</i> Fingerh (Chili Spur Pepper (Green))	3.02	0.11	0.52	0.02
<i>C. annum</i> L. var. <i>acuminatum</i> Fingerh. (Prick Man)	2.76	0.06	0.50	0.01
<i>C. annum</i> L. var. <i>acuminatum</i> Fingerh (Prick Num)	3.28	0.10	0.60	0.02
<i>C. annum</i> Linn. (Bell Pepper (Green))	2.52	0.10	0.56	0.02
<i>C. annum</i> Linn. (Bell Pepper (Yellow))	2.28	0.07	1.02	0.03
<i>C. annum</i> Linn. (Bell Pepper (Red))	2.60	0.07	0.71	0.02
<i>C. annum</i> L. var. <i>annuum</i> (Sweet Pepper)	2.68	0.17	0.50	0.03
<i>C. frutescens</i> Linn (Prick Hom Chiang Mai)	3.99	0.18	0.83	0.04
<i>C. frutescens</i> Linn (Prick Suan Tai)	3.49	0.01	0.78	0.00
<i>C. frutescens</i> Linn (Prick Karen)	3.20	0.24	0.93	0.07
<i>C. minimum</i> Roxb. (Thai Bird Chili, Cayenne Pepper)	2.40	0.05	0.72	0.02

Their r^2 values gave good linear in range of 0.9920-0.9999, however their calculated antioxidant activities were weak as measured by TEAC assay (Table 2). The TEAC values of *Solanum* sp. were in range of 0.01-0.03. The IC_{50} of *S. melongena* (Round Purple Eggplant) showed strong antioxidant activity of all *Solanum* sp. with value equal to 546.25 μ g, while the activity of *S. mammosum* was weakest with IC_{50} = 1706.95 μ g. The correlation between total phenols (x) and antioxidant activities (y) of *Solanum* sp. could be presented in equation, $y = 0.0054x + 0.0007$ with $r^2 = 0.5048$, Figure 1.

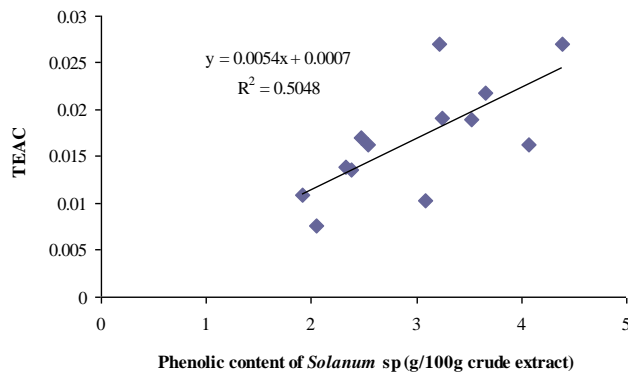


Figure 1 The correlation between total phenols and antioxidant activities of *Solanum* sp.

Table 2 Antioxidant activities calculated on TEAC basis and the IC_{50} of solanum and capsicum extracts.

Type of solanum and capsicum extracts	Equations			IC_{50} μg	TEAC
	slope ^a	intercept	r^2		
Trolox	5.0248	-0.9708	0.9985	10.14	1
<i>Solanum</i> sp.					
<i>S. aculeatissimum</i> Jacq. (Brinjal)	0.0428	3.8561	0.9990	1078.13	0.02
<i>S. aculeatissimum</i> Jacq (Ma Khuea Lueang)	0.0538	4.1344	0.9961	852.52	0.02
<i>S. aculeatissimum</i> Jacq. (Ma Khuea Torae)	0.0514	3.3855	0.9941	906.90	0.02
<i>S. aculeatissimum</i> Jacq. (Ma Khuea Bualoy)	0.0639	4.5556	0.9943	711.18	0.02
<i>S. aculeatissimum</i> (Ma Khuea Lai)	0.0312	0.6937	0.9947	1580.33	0.01
<i>S. aculeatissimum</i> (Ma Khuea Laiyai)	0.0293	2.5230	0.9981	1620.38	0.01
<i>S. torvum</i> Sw. (Ma Khuea Phuang)	0.0321	3.7662	0.9978	1440.31	0.01
<i>S. melongena</i> L	0.0817	5.3711	0.9986	546.25	0.03
<i>S. melongena</i> L. var. <i>serpentinum</i> (Desf.) Bailey (Long Purple Eggplant)	0.0655	6.9620	0.9961	657.07	0.03
<i>S. melongena</i> L. var. <i>serpentinum</i> (Desf.) Bailey (Long Eggplant)	0.0463	2.2046	0.9969	1032.30	0.01
<i>S. mammosum</i>	0.0279	2.376	0.9966	1706.95	0.01
<i>S. wrightii</i> Benth)Potato Tree(0.062	1.9551	0.9986	774.92	0.02
<i>S. stramonifolium</i> Jacq	0.0403	4.3369	0.9955	1133.08	0.02
<i>S. trilobatum</i> L.	0.0557	4.0124	0.9936	825.63	0.02
<i>Capsicum</i> sp.					
Capsaicin	0.0033	2.5150	0.8610	14389.39	0.01
<i>C. annuum</i> L.var.grossum (Red Chili)	0.0154	4.0754	0.9943	2982.12	0.01
<i>C. annuum</i> L. var. <i>acuminatum</i> Fingerh. (Yellow Chili)	0.0308	3.7287	0.9965	1502.32	0.01
<i>C. annuum</i> L. var. <i>acuminatum</i> Fingerh (Chili Spur Pepper (Red))	0.0243	3.4993	0.9982	1913.61	0.01
<i>C. annuum</i> L. var. <i>acuminatum</i> Fingerh (chili Spur Pepper (Green))	0.0472	4.503	0.9953	963.92	0.02
<i>C. annuum</i> L. var. <i>acuminatum</i> Fingerh. (Prick Man)	0.0464	2.6609	0.9920	1020.24	0.01
<i>C. annuum</i> L. var. <i>acuminatum</i> Fingerh (Prick Num)	0.0544	3.3924	0.9970	856.76	0.02
<i>C. annuum</i> Linn. (Bell Pepper (Green))	0.0384	3.2088	0.9993	1218.52	0.01

<i>C. annuum</i> Linn. (Bell Pepper (Yellow))	0.0441	3.9195	0.9987	1044.91	0.02
<i>C. annuum</i> Linn. (Bell Pepper (Red))	0.0610	3.2832	0.9999	765.85	0.02
<i>C. annuum</i> L. var. <i>annuum</i> (Sweet Pepper)	0.0363	3.456	0.9966	1282.20	0.01
<i>C. frutescens</i> Linn (Prick Hom Chiang Mai)	0.0353	3.4799	0.9964	1317.85	0.01
<i>C. frutescens</i> Linn (Prick Suan Tai)	0.0192	3.2218	0.9925	2436.37	0.01
<i>C. frutescens</i> Linn (Prick Karen)	0.0111	3.0139	0.9997	4232.98	0.01
<i>C. minimum</i> Roxb. (Thai Bird Chili, Cayenne Pepper)	0.0149	3.6783	0.9956	3108.84	0.01

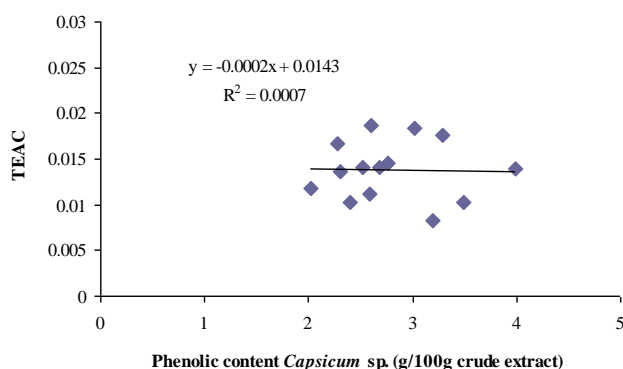


Figure 2 The correlation between total phenols and antioxidant activities of *Capsicum* sp.

This result indicated that 50.48 percent of *Solanum* sp. antioxidant activities accessed from their total phenolic contents. For *Capsicum* sp., their TEAC values were in range of 0.01-0.02. The capsaicin, an active capsaicinoid compound in *Capsicum* sp, also showed weak antioxidant activity (TEAC = 0.01). This implied that capsaicin was not a source of antioxidant activities of *Capsicum* sp. The *C. annuum* (red bell pepper) gave the highest radical scavenger activities in *Capsicum* sp. with $IC_{50} = 765.85 \mu\text{g}$ and *C. minimum* demonstrated the weakest activities with $IC_{50} = 3108.84 \mu\text{g}$. Comparing between maturity stage, the chili spur pepper (red) contained lower total phenolic contents in crude extract and lower antioxidant activity than chili spur pepper (green). For bell pepper in green, yellow and red stage, they contained not significantly different total phenolic contents, however the red and yellow one gave higher antioxidant activities than the green one. Although the *C. frutescens* contained highest total phenols, its antioxidant activities were lower than *C. annuum*. The drying temperature of this study (55°C) might affect the antioxidant activity of capsicum. Vega-Galvez *et al.* (2009) report that red peppers (*C. annuum*) that are dried at 80° and 90°C showed higher antioxidant activities than those that are dried at 50° , 60° and 70°C , since the long drying period may reduce the antioxidant activity [41]. The correlation between total phenols (x) and antioxidant activities (y) of *Capsicum* sp. was showed in Figure 2 with equation, $y = -0.0002 + 0.0143$, $r^2 = 0.0007$. This result suggested the weak correlation between total phenolic contents and antioxidant activities of *Capsicum* sp. This result corresponded to the report of Deepa *et al.* (2006) that the red sweet pepper exhibits weak correlation between total phenolic and antioxidant activity which are measured by ferric reducing antioxidant power and DPPH assay [42].

CONCLUSION

The *Solanum* and *Capsicum* sp. are worldwide produced and eaten as food. From this present study, their *in vitro* antioxidant activities in term of TEAC were rather weak. These might because of their weak correlation between total phenols and antioxidant activities. However, *Solanum* and *Capsicum* sp are still interesting, since they contain high dietary nutritional values and have some beneficial pharmacological activities.

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