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Research Article
Phytochemical Contents and Antioxidant Activity of Thai Sweet Potato (*Ipomoea batatas* L.) Extracts

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Abstract

Background and Objectives: Sweet potato composes different phytochemicals which are beneficial effects on human health. This study aimed to evaluate the phytochemical contents and their antioxidant activity of Thai sweet potato (*Ipomoea batatas* L.) planted in the area of northeastern, Thailand. **Materials and Methods:** The five different colours of Thai sweet potato were collected and extracted by ethanol-HCl. The various phytochemicals in the extracts were evaluated and antioxidant activity by different assays. Correlation analysis of phytochemicals and antioxidant activity were performed as well as High-Performance Liquid Chromatography (HPLC) analysis. **Results:** Total flavonoids were found the highest contents in all colours followed by total phenolics while total saponin content was the lowest substance. The antioxidant activity demonstrated that the extracts of Thai sweet potato had high scavenging activity against both DPPH and ABTS radicals. With reducing power activity, the extracts had more potential capacity on cupric than ferric. The different contents and antioxidant activity of the extracts were influenced by the colour of the potato. A high positive correlation between total phenolic, flavonoid and all antioxidant methods was observed. The HPLC analysis revealed that the main substances in the Thai sweet potato extracts were quercetin, catechin, gallic acid and caffeic acid. **Conclusion:** Thai sweet potato could be suggested as an alternative source of diet for humans according to its phytochemicals and antioxidant activity.

Key words: Antioxidant activity, area, correlation, phytochemicals, health-promoting benefits, source, Thai sweet potato

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The presence of Non-Communicable Diseases (NCDs) resulted in the degenerative function of many organs in the human body. This condition is well known caused by oxidants or free radicals as oxidative stress and induced different types of degenerative diseases[1-4]. The substances that can be inhibited by the harmful oxidants have been discovered and focused[5-10]. Plants have been proved as good sources of antioxidant compounds. The substances derived from plants are called "phytochemicals" which are composed of various types, especially phenolic compounds[11-15]. They have also been exhibited of various biological activities[16-23] with promising sequent as a medicinal herb. Thailand is the one country that consisted of plant diversity. However, various plants still have no evidence recorded and lack bioactive compounds information.

Sweet potato (*Ipomoea batatas* L.) is known as an important crop for human food, cultured in many areas in Asia, the America and Africa[24]. The most producer of sweet potatoes in the world is China[25]. Sweet potato is composed of many kinds of nutrients for health supplement[26]. With its colours, the sweet potato can be classified by colours such as white, yellow, orange, red and purple. Most components of sweet potato are starch (50-80%)[27] and others are essential amino acids, vitamins, minerals and fibers[28,29]. Moreover, the sweet potato also contained many kinds of phytochemicals[30,31]. Many reports are suggesting that the bioactive substances of sweet potatoes showed a high level of antioxidant, anti-inflammatory activities as well as other biological activities[24,25].

Thailand is one country of plant diversity and is located in tropical areas. The sweet potato is generally cultivated in Thailand, especially in the northeastern area. The previous reports indicated that completely different chemical compositions were influenced by sweet potato colours[32]. However, limited data is currently available on the bioactivities of phytochemicals from Thai sweet potato. Therefore, the present works aimed to extract phytochemicals from different colours of Thai sweet potato and to analyze their antioxidant activity *in vitro*. Additionally, the correlation and individual substances were performed and discussed.

MATERIALS AND METHODS

Study area: All parts of the experiments were done at the Department of Chemistry, Faculty of Science, Mahasarakham University, Maha Sarakham, Thailand, for 6 months from March 10 to September 30, 2021.

Materials: The different colours, white (W), purple (P), dark orange (DO), light orange (LO) and cubic orange (CO) of sweet potato (*Ipomoea batatas* L.) roots were received from a local market in Roi-Et, Maha Sarakham and Kalasin Provinces, Thailand. The flesh of the sweet potato was separated from texture, dried in an oven and ground to powder. The dried samples were kept in a sealed bag before use.

Methods

Crude extraction: The 15 g of each sweet potato powder was extracted by using ethanol/hydrochloric acid (99:1 v/v) (150 mL) for 24 hrs. The triplicate extraction was performed for each sample colour. A rotary evaporator was used for the concentration of the extracts. For analysis, the concentrated extract was dissolved with ethanol.

Phytochemical investigation: The phytochemicals contained in the sweet potato extracts include total phenolic content (TPC), total flavonoid content (TFC), total saponin content (TSC), total condensed-tannin content (CDT) and total proanthocyanidin content (TPAC) were analyzed following the previous reports. The TPC was determined using Folin-Ciocalteu reagent following the previous method[33], while the TFC was determined using $AlCl_3$ solution following the previous method[34]. The vanillin-ethanol was used for TSC[35] and TPAC[36] following the previous methods. Finally, the CDT was also determined following the previous method[37] using catechin as standard.

Antioxidant activity: This study used colourimetric spectrophotometry including $DPPH^{\bullet}$ and $ABTS^{\bullet+}$ radicals scavenging activity[38] for testing antioxidant activity of the sweet potato extracts. The results were expressed by the half inhibition value of original free radicals (IC_{50}). Moreover, the metal-reducing power activity by the ferric reducing antioxidant power (FRAP)[38] and cupric reducing antioxidant capacity (CUPRAC)[39] was also applied for antioxidant activity investigation. The FRAP and CUPRAC results were expressed as μM Fe^{2+}/g DW and mg TE/g DW, respectively.

Quantitative analysis of phenolic compounds: Phenolic contents were identified using the RP-HPLC analysis and the ten external standard compounds were used for comparison. The Inertsil ODS-3, C18 column with a diode array detector was applied for compound separations. The flow rate of separation solvent, elution system as well as analysis condition was followed by previous report[34]. The wavelength from 200-600 nm was recorded to obtain each standard spectra.

Statistical analysis: The assays were performed for triplicate to obtain Means±Standard Deviation (SD). Duncan and Pearson's tests were used to find the significance with $p<0.05$ of the data and correlation analysis, respectively.

RESULTS

Characteristics of Thai sweet potato: The five samples of Thai sweet potato with different colours were chosen for this study. Figure 1a-e showed the sweet potato characteristic of all samples, (a) White, (b) Purple, (c) Dark orange, (d) Light orange and (e) Cubic orange. The differences in shapes, the colour of skin and pulp and sizes were used for separation.

Investigation of total phytochemicals: The total phytochemicals found in the Thai sweet potato extracts contents as shown in Table 1. Generally, TFC found the highest substances in all colours, followed by TPC and CDT»TPAC. The lowest substance is TSC. The TPC and TFC found the highest in DO extract (71.16±0.48 mg GAE and 123.39±0.46 mg QE), then W (49.51±0.59 mg GAE and 85.50±0.82 mg QE) and CO (48.44±0.16 mg GAE, 58.98±0.75 mg QE). The TFC and TPC showed a similar trend in contents. However, the TFC was higher than TPC approximately one-third folds. The TSC found the highest content in DO extract (7.09±0.17 mg AES), followed by CO (3.01±0.19 mg AES) and P (2.99±0.32 mg AES), respectively. The CDT and TPAC were found in similar contents in all extracts with the highest in P (32.46±0.47 and 33.03±0.80 mg CE for CDT and TPAC, respectively). Moreover, the CO extract composed of CDT and TPAC closed up to the P extract of 31.77±0.29 and 28.97±0.83 mg CE, respectively.

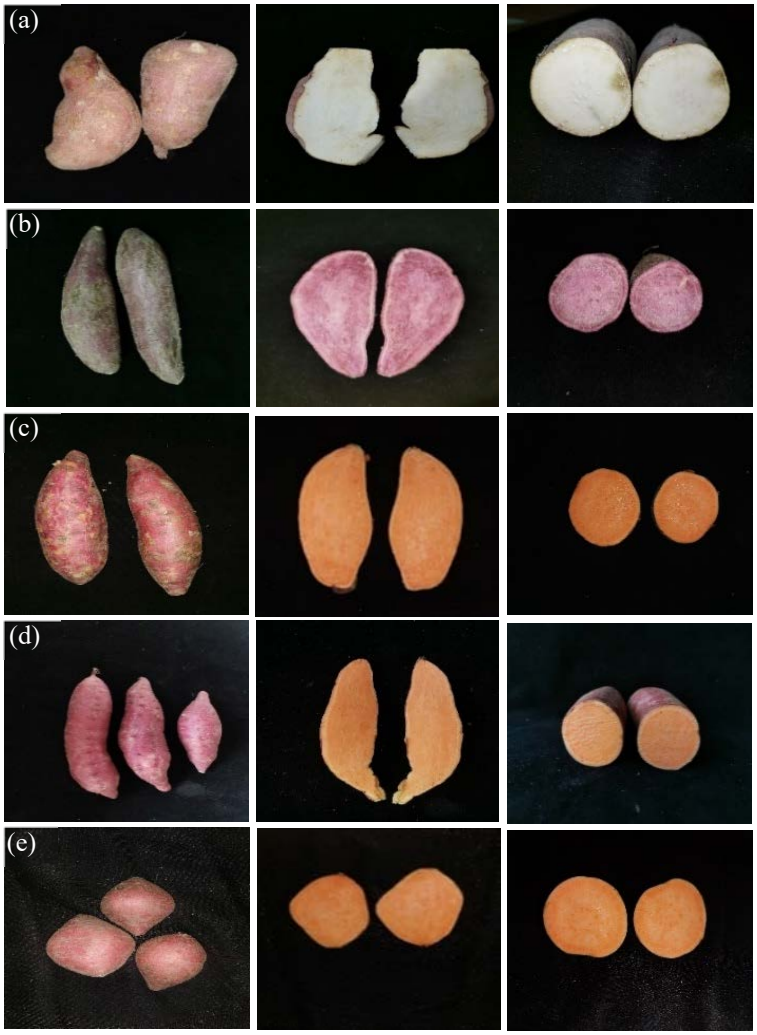

Fig. 1(a-e): Characteristics of Thai sweet potato divided by colours, (a) White, (b) Purple, (c) Dark orange, (d) Light orange and (e) Cubic orange

Table 1: Total phytochemicals in the different colours of Thai sweet potato extracts

Extracts	TPC (mg GAE/g DW)	TFC (mg QE/g DW)	TSC (mg AES/g DW)	CDT (mg CE/g DW)	TPAC (mg CE/g DW)
W	49.51±0.59^{c}	85.50±0.82^{d}	1.26±0.15^{a}	10.17±0.65^{a}	10.16±0.66^{a}
P	41.03±0.85^{b}	55.17±0.81^{b}	2.99±0.32^{c}	32.46±0.47^{d}	33.03±0.80^{d}
DO	71.16±0.48^{d}	123.39±0.46^{e}	7.09±0.17^{d}	25.13±0.69^{c}	22.79±0.88^{c}
LO	32.32±0.23^{a}	41.30±0.87^{a}	2.78±0.46^{b}	15.82±0.71^{b}	15.79±0.43^{b}
CO	48.44±0.16^{c}	58.98±0.75^{c}	3.01±0.19^{c}	31.77±0.29^{d}	28.97±0.83^{e}

Results are expressed as Mean±SD of triplicate measurements, Means with different letters in the same column represent significant differences at p<0.05, TPC: Total phenolic content, TFC: Total flavonoid content, TSC: Total saponin content, CDT: Total condensed tannin content, TPAC: Total proanthocyanidin content, the different colours of Thai sweet potatoes, W: White, P: Purple, DO: Dark orange, LO: Light orange and CO: Cubic orange

Table 2: Antioxidant activity of the Thai sweet potato extracts

Extracts	DPPH (IC_{50} mg mL^{-1})	ABTS (IC_{50} mg mL^{-1})	FRAP (μM Fe^{2+}/g DW)	CUPRAC (mg TE/g DW)
W	0.23±0.01^{b}	0.11±0.00^{b}	0.47±0.01^{a}	175.69±0.80^{d}
P	0.27±0.00^{b}	0.14±0.00^{c}	0.78±0.00^{c}	163.12±0.51^{c}
DO	0.15±0.00^{a}	0.09±0.00^{a}	1.48±0.01^{e}	274.87±0.71^{e}
LO	0.35±0.01^{c}	0.14±0.00^{c}	1.18±0.00^{d}	160.31±0.61^{b}
CO	0.37±0.01^{c}	0.17±0.00^{d}	0.65±0.00^{b}	134.14±0.97^{a}

Results are expressed as Mean±SD of triplicate measurements, Means with different letters in the same column represent significant differences at p<0.05, DPPH: 2,2-diphenyl-1-picrylhydrazyl, ABTS: 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt, FRAP: Ferric reducing antioxidant power, CUPRAC: Cupric reducing antioxidant capacity

Table 3: Correlation coefficient (r) analysis

	TPC	TFC	TSC	CDT	TPAC	DPPH	ABTS	FRAP	CUPRAC
TPC	1	0.969**	0.310	0.189	-0.040	-0.911**	-0.909**	0.816**	0.963**
TFC		1	0.220	0.051	-0.202	-0.927**	-0.910**	0.700**	0.970**
TSC			1	0.129	0.279	-0.158	-0.163	0.444*	0.372
CDT				1	0.802**	-0.077	-0.158	0.574**	0.186
TPAC					1	0.219	0.086	0.512*	-0.036
DPPH						1	0.952**	-0.598**	-0.882**
ABTS							1	-0.643**	-0.852**
FRAP								1	0.806**
CUPRAC									1

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed), TPC: Total phenolic content, TFC: Total flavonoid content, TSC: Total saponin content, CDT: Total condensed tannin content, TPAC: Total proanthocyanidin content, the different colours of Thai sweet potatoes, W: White, P: Purple, DO: Dark orange, LO: Light orange and CO: Cubic orange, DPPH: 2,2-diphenyl-1-picrylhydrazyl, ABTS: 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt, FRAP: Ferric reducing antioxidant power, CUPRAC: Cupric reducing antioxidant capacity

Antioxidant test: As shown in Table 2, the Thai sweet potato extracts have high antioxidant activity. The free radicals scavenging activity (DPPH and ABTS assays) is expressed by IC_{50} values. In general, the DO extract showed the lowest IC_{50} values in both DPPH and ABTS. However, the extracts have a more specific effect on ABTS than DPPH assays. The W extract (0.23 and 0.11 mg mL^{-1}) showed second runner up for DPPH and ABTS free radicals scavenging following by P (0.27 and 0.14 mg mL^{-1}), LO (0.35 and 0.14 mg mL^{-1}) and CO (0.37 and 0.17 mg mL^{-1}), respectively. Note the P and LO extracts have the same ABTS free radical scavenging activity (0.14 mg mL^{-1}). With ferric and cupric reducing power assays, the DO extract showed higher activity (1.48 μM Fe^{2+} and 274.87 mg TE) than other colours. The LO extract has second-order reducing power by FRAP assay (1.18 μM Fe^{2+}), following by P (0.78 μM Fe^{2+}), CO (0.65 μM Fe^{2+}) and lowest in W extract (0.47 μM Fe^{2+}). The extracts showed higher reducing power on cupric than ferric. The W extract has second-order reducing power by CUPRAC assay (175.69 mg TE), followed by P (163.12 mg TE), LO (160.31 mg TE) and lowest in CO extract (134.14 mg TE).

Analysis of correlation: As shown in Table 3, all tested phytochemicals showed low correlate values together. However, the TPC and TFC found high positive correlation (r = 0.969 or 96.9%) as well as the CTC and TPAC (r = 0.802 or 80.2%). The TPC (r = -0.911 or 91.1%) and TFC (r = -0.927 or 92.7%) have the highest negative correlation to DPPH. They were also had the negative correlation with ABTS assay (r = -0.909 or 90.9% and r = -0.910 or 91% for TPC and TFC, respectively). Other substances showed low correlation on antioxidant assays. Both TPC and TFC have high correlation values for FRAP (r = 0.816 or 81.6% and r = 0.700 or 70%) and the highest correlation values on CUPRAC assay (r = 0.963 or 96.3% and r = 0.970 or 97%). Other substances showed moderate correlation on FRAP assay (r = 0.444 or

Table 4: Individual phenolic contents (mg g^{-1} DW) in Thai sweet potato extracts

Extracts	Gallic acid	Ferulic acid	Caffeic acid	p-Coumaric acid	Catechin	Epicatechin	Rutin	Myricetin	Resveratrol	Quercetin
W	1.49±0.01^{a}	0.36±0.01^{b}	8.63±0.01^{e}	0.16±0.01^{a}	0.38±0.01^{a}	0.17±0.01^{b}	0.04±0.00^{a}	0.06±0.00^{a}	0.06±0.00^{a}	2.63±0.01^{a}
P	1.51±0.01^{a}	0.44±0.01^{c}	2.01±0.03^{c}	0.46±0.00^{c}	1.78±0.01^{d}	0.19±0.01^{b}	0.04±0.00^{a}	0.38±0.00^{c}	0.13±0.00^{b}	2.92±0.02^{a}
DO	ND	0.38±0.00^{b}	3.84±0.01^{d}	0.27±0.01^{b}	1.04±0.02^{c}	ND	0.01±0.00^{a}	0.13±0.01^{b}	0.10±0.01^{b}	12.53±0.01^{c}
LO	1.93±0.01^{b}	0.31±0.00^{a}	1.25±0.05^{a}	0.17±0.01^{a}	0.72±0.01^{b}	0.17±0.01^{b}	0.02±0.00^{a}	0.02±0.00^{a}	0.03±0.00^{a}	3.70±0.02^{b}
CO	1.65±0.01^{b}	0.31±0.00^{a}	1.71±0.08^{b}	0.17±0.01^{a}	0.56±0.01^{b}	0.10±0.01^{a}	0.02±0.00^{a}	0.06±0.01^{a}	0.01±0.00^{a}	3.98±0.02^{b}

Results are expressed as Mean±SD of triplicate measurements, means with different letters in the same column represent significant differences at $p<0.05$, W: White, P: Purple, DO: Dark orange, LO: Light orange and CO: Cubic orange and ND: Not detected

44.4%, r = 0.574 or 57.4 % and r = 0.512 or 51.2% for TSC, CDT and TPAC, respectively) and were low correlation values on CUPRAC assay. Among antioxidant methods, DPPH and ABTS showed higher correlation values than that FRAP and CUPRAC assays.

Quantitative analysis: Table 4 showed individual phenolic contents obtained from RP-HPLC analysis. In overview, the contents and types of phenolic compounds were varied by the colour of Thai sweet potato. Gallic acid (~1.5-1.9 mg g^{-1} DW) found similar contents in all colours, except DO. The obtained results were a similar trend with ferulic acid in the range of 0.31-0.44 mg g^{-1} DW. The caffeic acid found dramatic variation among colours that W has the highest content (8.63 mg g^{-1} DW) while LO (1.25 mg g^{-1} DW) has the lowest content. The p-coumaric acid was found similar in W, LO and CO with low content (~0.17 mg g^{-1} DW) and a slight increase in DO (0.27 mg g^{-1} DW) and P (0.46 mg g^{-1} DW), respectively. The dominant flavonoids were quercetin (2.63-12.53 mg g^{-1} DW) and catechin (0.38-1.78 mg g^{-1} DW) which found the highest in DO and P, respectively. Other substances, epicatechin, rutin, myricetin and resveratrol were found in low contents. The flavonoid in P was slightly higher in contents than in other colours.

DISCUSSION

Table 1 indicated that the Thai sweet potato contained the TPC higher content than the purple sweet potato starch (10-15 mg GAE g^{-1} DW) and the starch before (13 mg g^{-1} DW) hot stream[40,41]. Moreover, the obtained TPC was in higher content than the Philippines sweet potato starch (15-36 mg g^{-1} DW)[42]. However, the TPC in Thai sweet potato has lower content than the TPC found in the leaves of Japanese sweet potato (63-135 mg g^{-1} DW), except DO[43] and Portugal sweet potato (120-132 g GAE g^{-1} DW). The Thai sweet potato composed higher TPC content than the TPC from Phiji and Taiwanian sweet potato (24-28 and 3-13 mg g^{-1} DW, respectively)[24]. The TPC in Thai sweet potato has similar content within American purple sweet potato (40 mg g^{-1} DW), but is higher TPC than in orange and yellow cultivars (2-3 mg g^{-1} DW)[30]. The TFC of Thai sweet potato found higher contents (~41-123 mg g^{-1} DW) than TPC and were also in higher contents than the TFC found in three varieties of purple sweet potato planted in China (~0.28-0.40 mg g^{-1} DW)[44].

The important substance in the sweet potato is anthocyanins[45]. It involves pink, red, purple and blue of some fruits and flowers[46]. Anthocyanidins are a core structure of anthocyanin which cross-linked with sugar molecules to form anthocyanin[47,48]. TPAC results are in agreement with the previous report[45] since they found that the sweet potato was composed of variable content of anthocyanidins from 0.32-13.92 mg g^{-1} DW. However, the TPAC in this study found higher content than American sweet potato (8.49 mg g^{-1} DW)[30] and Chinese sweet potato (6.57 mg g^{-1} DW)[49]. The CDT showed similar trends of contents as compared to the TPAC. This might be according to the CDT and TPAC are the same molecular structure. The TSC found the lowest contents compared to others. This substance generally involved the taste of plants, especially the bitter taste. Therefore, it does not a surprise that the sweet potato composed this substance in low content. The finding results indicated that phytochemicals in Thai sweet potato were variable contents by various factors including cultivars, growth stage, colour, parts, genetics, climate, geography and culturing area[50], methods and instrument for analysis[44].

The antioxidant activity assay is a popular process to confirm the biological activity of plant extract. The antioxidant substances from the plant would be donated H-atom to DPPH to from stable DPPH-H[51,52]. The scavenging activity of Thai sweet potato against DPPH and ABTS radicals is very low within similar potent as previous work on polysaccharides extracted from China sweet potato (variety NING No. 1)[25]. However, the ABTS radical assay showed a higher scavenging value than the DPPH. This means the extracts from Thai sweet potato expressed scavenging ABTS radicals with more potent capacity than in DPPH. The variable capacity might be caused by the different phytochemical types and contents composed in the purple sweet potato[30,46,53]. Besides antioxidant assays, the ferric (FRAP) and cupric (CUPRAC) reducing antioxidant power are also popularly used. The reducing value is directly revealed of antioxidant activity[54]. This study indicated that the Thai sweet potato extract expressed reducing power activity similar to the activity of polysaccharide extracted from Chinese purple sweet potato[25], but in higher activity than polysaccharide extracted from *G. scabra*[55].

Flavonoids are the large phenolic substances found in the sweet potato which were in agreement with the previous reported[56]. Both phenolic acids and flavonoids are concerned the scavenging and reducing power activities[11]. The results in this study found that quercetin and catechin are the main flavonoids in the Thai sweet potato within agreement with previous reports[57,58]. However, low contents of resveratrol, rutin and myricetin were also observed. These substances were found generally in fruit pulp with low content[59].

In future studies, other nutrients such as folate, protein, ascorbic acid, carotenoids and advanced analytical techniques for bioactive substances would be performed to obtain more information.

CONCLUSION

The phytochemicals and antioxidant activities in the Thai sweet potato extracts were investigated and discussed. All colours of Thai sweet potato are composed of various phytochemicals. The total flavonoids and phenolics are the most dominant types. Both substances are the main substances against free radicals and metal-reducing. Correlation analysis surely revealed that the antioxidant activity was affected by content and type of phytochemicals. Different pigmented potatoes composed slightly different contents of phytochemicals which were affected their biological activity. Therefore, further study of both other chemical substances and biological actions of the Thai sweet potato should be evaluated for being health benefits in the future.

SIGNIFICANCE STATEMENTS

This study evaluated the phytochemical contents and their antioxidant activity of the Thai sweet potato planted in northeastern, Thailand. The results indicated that the Thai sweet potato might be used as a health supplement diet for humans. Thus, the users about the Thai sweet potato as functional foods may be arrived at.

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