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EDITED BY
Shivraj Hariram Nile,
Zhejiang Chinese Medical University, China

REVIEWED BY
C. K. Sunil,
Indian Institute of Food Processing Technology, India
Suzy Munir Salama,
University of Malaya, Malaysia
Tânia Gonçalves Albuquerque,
Instituto Nacional de Saúde Doutor Ricardo Jorge (INSA), Portugal

*CORRESPONDENCE
Kunchit Judprasong
kunchit.jud@mahidol.ac.th

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Nutritive values and phytochemical compositions of edible indigenous plants in Thailand

Piyanut Sridonpai[1], Pichakorn Kongprapun[1], Nongnuch Sungayuth[2], Monruedee Sukprasansap[1], Chanika Chimkerd[1] and Kunchit Judprasong[1]*

[1]Institute of Nutrition, Mahidol University, Salaya, Nakhon Pathom, Thailand, [2]Division of Science and Liberal Arts, Mahidol University, Kanchanaburi, Thailand

Indigenous edible plants are important components of food systems that are linked to food security and are important sources of nutrients with potential health benefits. Since knowledge about Thailand's various indigenous plants is limited, this study determined the nutritive values and bioactive compounds contained in eight edible indigenous plants growing within the conservation area of the Electricity Generating Authority of Thailand, Srinakarind Dam, Kanchanaburi province. Plant samples were analyzed as fresh or cooked (blanched or boiled) depending on customary preparation and consumption habits. Results showed that shoots and young leaves of Jang (*Maerua siamensis* Kurz), Ta-Kuk (*Albizia lebbeck* (L.) Benth), Pak-Wan-Pa (*Melientha suavis* Pierre), and Som-kob (*Hymenodictyon exelsum* Wall.) have potential health benefits in terms of nutritive values (vitamin C, dietary fiber, protein) and bioactive compounds (carotenoids, phenolic compounds, antioxidant activity). Shoots and young leaves of Jang were highest in protein, dietary fiber, phenolic compounds, and antioxidant activity. Shoots and young leaves of Ta-Kuk had the highest vitamin C level and considerable amounts of protein, dietary fiber, phenolic compounds, antioxidant activity, and carotenoids. Loss of vitamin C and bioactive compounds occurred most often in boiled plants rather than those that were blanched, though carotenoids increased with either boiling or blanching. This study's important findings should be translated into practical knowledge and disseminated to local communities and at the national level to encourage plant conservation, nutrition education, and the increased consumption of these indigenous plants.

KEYWORDS

indigenous plants, nutrients, bioactive compound, cooking method, true retention

Introduction

Food and nutrition security is attained when all individuals access sufficient quantities of affordable, safe, and nutritious foods that are utilized to maintain healthy and active lives. One of several indigenous foods which have a potential to enhance the food and nutrition security in countries around the world, including Thailand, is the

indigenous plants. Numerous studies suggest that the indigenous herbs and plants are able to prevent or cure various human diseases in both non-communicable and infectious diseases (Aziz et al., 2018; Chaachouay et al., 2022; Eddouks et al., 2014; Gras et al., 2021; Phumthum and Balslev, 2020). Furthermore, some of these plants can be used for cooking and are beneficial to health (ESCOP (European Scientific Cooperative on Phytotherapy), 2021).

Based on this above-mentioned information and relevant to this present study, some indigenous plants, such as *Albizia lebbeck* (L.) Benth has a long history within Indian traditional medicine (Pal et al., 1995), in which its leaves and pods are used to treat cancer (Bobby and Wesely, 2012; Bobby et al., 2012; Desai and Joshi, 2019). *A. lebbeck* (L.) Benth. is found in dense deciduous forests in tropical and subtropical Asian countries, such as Cambodia, Indonesia, Laos, Malaysia, and Vietnam, Africa (Dy Phon, 2000), and Thailand, as well as being widely cultivated. It is a famous plant due to its high nutrients, phytochemicals, and medicinal values (Vasanthi et al., 2014; Sharma and Nishtha, 2015). The various parts of this plant have a wide range of pharmacological activities such as antimicrobial, anti-inflammatory, antioxidant, antitumor, antiulcer, antidiarrhoeal, and immunomodulatory capabilities (Saha and Ahmed, 2009; Vasanthi et al., 2014; Praengam et al., 2017). Additionally, some research found that the ethanolic extract of its leaves has been shown to ameliorate the effects of depression in animals (Velraj et al., 2010). *Maerua siamensis* (Kurz) Pax. is native to Southeast Asia. Extracts from its leaves and roots have demonstrated antioxidant activities and total phenolic content (Phosri, 2017; Chanthasri et al., 2018; Issuriya et al., 2019), while extracts from leaves and twigs of *M. siamensis* also have shown acetylcholinesterase inhibitory activity (Phosri, 2017). *Melientha suavis* Pierre is an edible local plant found in Southeast Asia, including Thailand. Previous reports have shown a radical scavenging effect and a strong antioxidant correlation between the FRAP scavenging activities and the flavonoid contents of extracts from its leaves and stems (Charoenchai et al., 2015; Sansomchai et al., 2021). *Hymenodictyon exelsum* Wall. is the indigenous plant found in South Asia, including India, Burma, and Thailand. It contains various phytochemicals and has been used in traditional medicine to treat ulcers, fever, tumors, and cancer. Some studies revealed that leaves and bark extracts of *H. exelsum* exhibited fantioxidant, anti-inflammatory, antimicrobial, antitumor, and anticancer properties (Kar et al., 2013; Rahman, 2015; Paramita et al., 2017).

In Thailand, indigenous plants are important food sources for communities living in and around forested areas. Consequently, data on the nutritive values and bioactive compounds of these plants are needed for dietary assessment, nutrition education, and health improvement. An earlier study reported 10 years ago provided information on nutrient content, bioactive compounds, and the health benefits of 40 species of indigenous plants based on 118 samples (Charoenkiatkul et al., 2012). This previous study was conducted within the conservation area of the Plant Genetic Conservation Project under the Royal Initiative of Her Royal Highness Princess Maha Chakri Sirindhorn in Kanchanaburi province, Western Thailand. This previous study's information had the potential to be distributed to communities to encourage the plants' cultivation and consumption, improve nutrition and health, and promote the conservation of these plant species. However, it had limitations in terms of sample collection and analysis ($n = 1$). Moreover, very little information exists about the biodiversity of Thailand's forests in terms of the health and nutritional benefits of many indigenous plants. Thereby, the present study was carried out in 2019 to explore indigenous plant foods within the conservation area of the Plant Genetic Conservation Project under the Royal initiative of Her Royal Highness Princess Maha Chakri Sirindhorn in the area of the Electricity Generating Authority of Thailand, Srinakarind Dam, Kanchanaburi province. This new survey's objective was to determine the nutritional potential of Thai indigenous plants in terms of nutrients, bioactive compounds, as well as antioxidant activities and carotenoid contents.

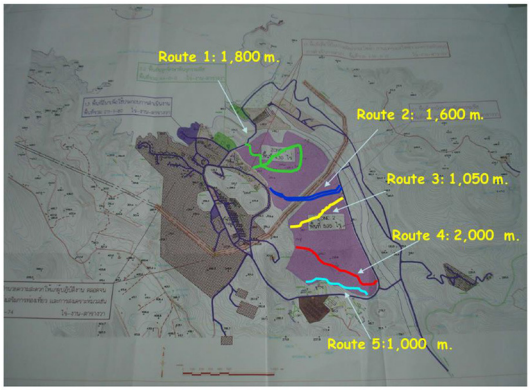

FIGURE 1
Study sites, five routes, at Srinakarind Dam, Kanchanaburi province, Thailand.

Materials and methods

Sample collection and preparation

This study was conducted along five routes (Figure 1) within the Plant Genetic conservation area at four separate time periods from January to September 2019. The eight commonly consumed indigenous plants collected for this study were identified and confirmed by local people and botanists. These plants are selected based on their being commonly consumed by local people and available in the study's areas. Information

TABLE 1 List of selected indigenous plants in the study.

Thai name	Scientific name	Edible part	Cooking method
Jang	*Maerua siamensis* (Kurz) Pax.	Shoots and young leaves	Blanch 1 min
Pak-Wan-Pa	*Melientha suavis Pierre*	Shoots and young leaves	Boil 3 min
Ta-Kuk	*Albizia lebbeck* (L.) Benth	Shoots and young leaves	Boil 2 min
Ka-Pee-Jun	*Millettia brandisiana* Kurz	Shoots and young leaves	No cooking due to commonly eaten as raw
Pak-God	*Diplazium esculentum* (Retz.) Swartz-*mossambicus*	Shoots and young leaves	Blanch 1 min
Wan-Pro	*Kaempferia roscoeana* Wall.	Young leaves and leaves	Blanch 1 min
Ka-Tur	*Zingiber zerumbet* L. (Sm.)	Flowers	Boil 4 min
Som-Kob	*Hymenodictyon exelsum* Wall.	Shoots and young leaves	Blanch 1 min

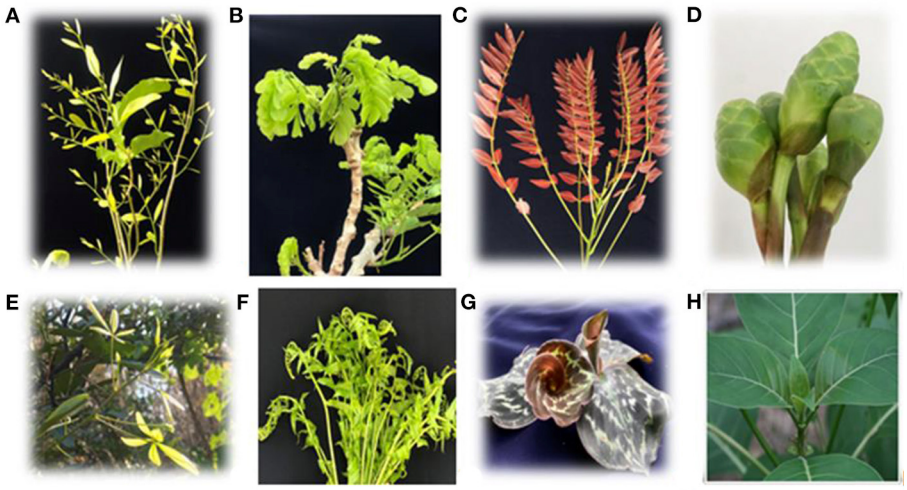

FIGURE 2
Photographs of Pak-Wan-Pa **(A)**, Ta-Kuk **(B)**, Ka-Pee-Jun **(C)**, Ka-Tur **(D)**, Jang **(E)**, Pak-God **(F)**, Wan-Pro **(G)**, and Som-Kob **(H)**.

about these plants and photographs are presented in Table 1 and Figure 2. Plant samples were kept in dark plastic bags to protect the sunlight and then transported *via* an ice-box to the ISO/IEC 17025 laboratory at the Institute of Nutrition, Mahidol University.

At the laboratory, the edible part of each sample was collected and recorded. Each sample was washed with tap water, followed by washing twice with deionized water. After cleaning and removing excess water, cooked samples were blanched (plant to water ratio about 1:2) or boiled (plant to water ratio about 1:1) depending on each plant's commonly eaten method (Table 1). Weights before and after cooking (about 10 min post-heat treatment) were recorded. Thereafter, both fresh and cooked samples were homogenized using a food processor (Mara®, Thailand) and divided into two portions. For the first portion, each sample was stored in an acid-washed screw-capped plastic bottle at −20°C for nutrient analyses. For vitamin C analysis, each sample was weighed to about 20 g in a plastic bottle, then about 20 g 10% MPA was added, mixed together, and then kept in a freezer. For the second portion, each sample was dried using a freeze dryer (Heto powerdry PL 9000), ground, vacuum-packed in laminated aluminum foil bags, and stored at−20°C for determination of bioactive compound and antioxidant activities.

Nutrient determination

Nutrient analysis was conducted using the standard AOAC method (2019) (Saha and Ahmed, 2009). All samples were analyzed at the ISO/IEC 17025:2017 accredited laboratory of the Institute of Nutrition, Mahidol University, which analyzed proximate compositions, vitamins, and minerals in duplicate analyses. All values were presented per 100 g fresh sample.

Proximate composition

Total nitrogen was determined using the Kjeldahl method, methods nos. 910.20 and 981.10 (Saha and Ahmed, 2009), and

calculated into protein content using specific (Jones) factors (N×6.25). Moisture content was determined by drying each sample in a hot air oven at 100 ± 2°C until a constant weight was obtained based on method nos. 990.19 and 952.23 [Association of Official Analytical Chemists (AOAC), 2016]. Crude fat content was determined by acid hydrolysis and extraction using petroleum ether in the Soxtec system (Avanti 2055, Foss Tecator, Sweden), method nos. 922.32 and 945.16 [Association of Official Analytical Chemists (AOAC), 2016]. Ash content was analyzed by incinerating all organic matter at 550 ± 5°C, method nos. 945.46 and 930.30 [Association of Official Analytical Chemists (AOAC), 2016]. Available carbohydrate was calculated using the following formula: 100-moisture-protein-fat-ash-dietary fiber; energy was calculated by Atwater factors (4 for protein and available carbohydrate, 2 for dietary fiber, and 9 for total fat). Total dietary fiber was analyzed using the enzymatic gravimetric method, method no. 985.29 [Association of Official Analytical Chemists (AOAC), 2016].

Vitamin and minerals

Based on the previous report of Charoenkiatkul et al. (2012), the potential of vitamin for the studied plants is only vitamin C. For vitamin C, high pressure liquid chromatography (HPLC) with a UV/Vis detector was used for analysis (Sánchez-Mata et al., 2000). Samples were extracted in 3% metaphosphoric acid and filtered to homogenate. Ascorbic acid was separated by reversed-phase HPLC with UV detection at 248 nm and quantified against an external ascorbic acid standards. For minerals, microwave digestion was used for sample decomposition to determine magnesium, iron, copper, and zinc using an inductively coupled plasma optical emission spectrophotometer (ICP-OES), method no. 984.27 [Association of Official Analytical Chemists (AOAC), 2016]. The acid solution dissolved from the ash residue was used for calcium, sodium, and potassium analyses by flame atomic absorption spectrophotometer (AAS), method no. 985.35 [Association of Official Analytical Chemists (AOAC), 2016]. Phosphorus was determined by the gravimetric method [Association of Official Analytical Chemists (AOAC), 2016].

Bioactive compound determination

Carotenoids contents

Samples were saponified and extracted according to the procedures of Sungpuang et al. (Sungpuang et al., 1999) with slight modification. In brief, freeze-dried samples were boiled with ethanolic potassium hydroxide with the addition of 10% (w/v) ascorbic acid, before being extracted with hexane, and then evaporated to dryness. The residue was reconstituted with mobile phase and then filtered through a 0.2 lm PTFE syringe filter. Chromatographic separation of individual carotenoids was modified slightly from the method described by Chitchumroonchokchai et al. (2017). The HPLC system for determining carotenoid content was carried out by Agilent 1100 series (Agilent Technologies, U.S.A.) and a photodiode array detector. The column used was an analytical YMC^{TM} C30 column (4.6 × 150 mm, 5 µm, Waters, Milford, MA). The mobile phase consisted of 98% (v/v) methanol with 2% (w/v) ammonium acetate (solvent A) and methyl tert-butyl ether (MtBE) (solvent B). Isocratic system with 80% solvent A and 20% solvent B was used at a constant flow rate at 0.6 ml/min at ambient temperature. Qualitative and quantitative evaluations of chromatograms were monitored at 450 and 470 nm using ChemStation (Agilent Technologies, USA). Individual carotenoids (lutein, zeathantin, β-cryptoxanthin, α-carotene, and β-carotene) were identified based on comparing retention time and the UV spectrum of unknown peaks to the authentic standards. Carotenoid contents were expressed as mg per 100 g sample.

Total phenolic contents

Total phenolic contents were determined by spectrophotometry using Folin–Ciocalteau reagent method (Lu et al., 2007) with slight modification. The absorbance was measured against the gallic acid standard at 760 nm. Total phenolic contents were expressed as mg gallic acid equivalent (GAE) per 100 g sample.

Antioxidant activity by oxygen radical absorbance capacity (ORAC) assay

The method for performing ORAC assay based on fluorescence probe and fluorescein has been described by Ou et al. (2002). Each sample's ethanolic extract was mixed with fluorescein solution and AAPH solution at 37°C. Fluorescence was recorded using a spectrofluorometer (Luminescence spectrophotometer, Perkin Elmer LS55, Maryland, USA) with an excitation wavelength of 493 nm and an emission wavelength of 515 nm. Results were calculated using the differences of areas under the curve between samples or standard (trolox) and blank. The ORAC values were expressed as µmol trolox equivalent (TE) per 100 g sample.

Determination of true retention during cooking

Samples were weighed (4 significant digits) before and after cooking. The data obtained, combined with the amounts of

TABLE 2 Nutrients in the indigenous plants (per 100 g fresh weight, $N = 3$).

Sample name	Energy (Kcal)[a]	Moisture (g)	Protein (g)	Total fat (g)	Available carbohydrate (g)[b]	Ash (g)	Dietary fiber (g)
Jang, fresh	96 ± 2	69.17 ± 1.31	9.51 ± 1.24	0.00 ± 0.00	9.29 ± 0.76	1.75 ± 0.19	10.29 ± 1.75
Jang, blanch	61 ± 9*	80.46 ± 2.74*	5.74 ± 1.07*	0.00 ± 0.00	6.09 ± 1.33*	0.78 ± 0.07*	6.93 ± 1.01*
Pak-Wan-Pa, fresh	70 ± 8	79.00 ± 2.10	5.97 ± 0.85	0.83 ± 0.07	7.31 ± 0.83	1.95 ± 0.09	4.95 ± 0.47
Pak-Wan-Pa, boil	60 ± 4*	81.78 ± 0.70	5.82 ± 0.60	0.92 ± 0.18*	4.14 ± 0.37*	1.25 ± 0.18*	6.09 ± 0.33
Ta-Kuk, fresh	64 ± 4	81.15 ± 1.49	7.70 ± 0.94	0.68 ± 0.08	4.14 ± 0.67	0.99 ± 0.06	5.35 ± 0.21
Ta-Kuk, boil	50 ± 3*	85.43 ± 0.63*	5.91 ± 0.47*	0.77 ± 0.10	2.30 ± 0.23*	0.48 ± 0.05*	5.11 ± 0.15
Wan-Pro, fresh	12 ± 1	94.75 ± 0.28	0.80 ± 0.01	0.07 ± 0.03	3.29 ± 0.33	1.17 ± 0.07	2.81 ± 0.18
Wan-Pro, blanch	10 ± 4	96.25 ± 1.05	0.69 ± 0.06*	0.00 ± 0.00*	2.21 ± 0.97	0.85 ± 0.04*	2.56 ± 0.17
Som-Kob, fresh	43 + 1	86.28 ± 0.34	2.21 ± 0.05	0.54 ± 0.14	4.05 ± 0.26	0.87 ± 0.04	6.06 ± 0.10
Som-Kob, blanch	43 + 1	87.41 ± 0.37	2.01 ± 0.06	0.78 ± 0.11*	4.20 ± 0.26	0.65 ± 0.04*	4.97 ± 0.08*
Ka-Tur, fresh ($N = 1$)	13	93.66	1.08	0.00	0.32	1.09	3.86
Ka-Tur, boil ($N = 1$)	10	95.13	0.80	0.00	0.21	0.70	3.16

[a]Energy was calculated by Atwater factors (4 for protein and available carbohydrate, 2 for dietary fiber, and 9 for total fat).
[b]Available carbohydrate was calculated using the following formula: 100-moisture-protein-fat-ash-dietary fiber.
*Values of each parameter in cooked vegetables were significantly different for a given variable ($p < 0.05$ paired sample t-test) compared to those of each fresh vegetable.

nutrients in raw and cooked plants, were used to calculate true retention (Murphy et al., 1975) as per the formula

$$\%\text{True retention} = \frac{\text{nutrient per 100 g of cooked food} \times \text{weight of cooked food}}{\text{nutrient per 100 g of raw food} \times \text{weight of raw food}} \times 100$$

Statistical analysis

Each nutrient in the plant samples was reported as mean values ± standard deviation from three individual samples. The paired samples t-test compares the means of two measurements (fresh and cooked) taken from the same individual sample was used to indicate significance difference ($p \leq 0.05$) of effect of cooking of each parameter. Statistical analysis was performed using IBM® (Hampshire, UK) SPSS Statistics for Window, Version 19.0.

Results and discussion

The edible portions of shoots and young leaves of Jang, Pak-Wan-Pa, Ta-Kuk, Ka-Pee-Jun, Pak-God, and Som-Kob ranged from 52 to 66%, while these portions for Ka-Tur and Wan-Pro ranged from 72 to 95%, respectively.

Proximate compositions

The proximate compositions of the eight indigenous plant varieties is shown in Table 2 below. Approximately 69–96% of composition was water. Cooked indigenous plant samples had an increased moisture content of 1–5%, which may be due to the water used for blanching or boiling. The protein content of samples ranged from 0.8 to 9.5 g/100 g fresh weight (FW). Protein content was greatest in Jang, Ta-Kuk, and Pak-Wan-Pa. Dietary fiber was the main nutrient contained in the samples, ranging from 2.6 to 10.3 g/100 g FW. The shoots and young leaves of Jang contained the highest amount of dietary fiber, followed by Som-Kob, Ta-Kuk, Pak-Wan-Pa, Ka-Tur, and Wan-Pro. Available carbohydrate content ranged from 2.2 to 9.3 g/100g FW. Fat content in all samples was <1 g/100g FW. Protein, dietary fiber, and fat contents in this study were similar and showed no significant differences ($p \geq 0.05$) with those previously reported (Charoenkiatkul et al., 2012), i.e., Pak-Wan-Pa (protein 5.97 vs. 6.5 g/100g, dietary fiber 4.95 vs. 6.5 g/100 g, fat 0.83 vs. 1.2 g/100 g), Ta-Kuk (protein 7.70 vs. 7.30 g/100 g, dietary fiber 5.35 vs. 5.6 g/100 g, fat 0.68 vs. 0.60 g/100 g), Wan-Pro (protein 0.80 . 0.80 g/100 g, dietary fiber 2.81 vs. 3.20 g/100 g, fat 0.07 . 0.10 g/100 g), and Ka-Tur (protein 1.08 vs. 0.90 g/100 g, dietary fiber 3.86 vs. 4.80 g/100 g, fat 0 vs. 0.10 g/100 g), respectively. Protein content in this study was lower than that reported from Egypt, which was 15.14 g/100 g for Ta-Kuk (Hawary et al., 2011). For cooked vegetables, most proximate compositions decreased significantly ($p \leq 0.05$)

compared to those of the same fresh vegetables. A wide range of decreasing protein content was observed (2.5% in Pak-Wan-Pa to 39.6% in Jang). A similar decreasing pattern was also found in ash after cooking (25.3% in Som-Kob to 55.4% in Jang). Nutrient amounts decreased slightly after cooking, which may have been caused by the dissolution of nutrients into the water used for cooking (Lyimo et al., 1990).

Vitamins and minerals

Vitamin C and mineral contents in the eight varieties of indigenous plants are presented in Table 3 below. The shoots and young leaves of Ta-Kuk contained the highest amount of vitamin C (212 mg/100 g FW), followed by Pak-Wan-Pa, Jang, and Ka-Pee-Jun (146 ± 19, 126 ± 7, and 27 ± 9 mg/100 g FW, respectively). The vitamin C contents of Pak-God (7 ± 1 mg/100g), Wan-Pro, Ka-Tur, and Som-Kob were <10 mg/100 g FW. A previous report (Charoenkiatkul et al., 2012) showed lower levels of vitamin C in Pak-Wan-Pa (146 vs. 99 mg/100 g) and Ta-Kuk (126 vs. 161 mg/100 g), while Wan-Pro was higher (2 vs. 3 mg/100 g). There were significant vitamin C losses ($p \leq 0.05$) in cooked vegetables compared to that of fresh vegetables (ranging from 34.9% in Jang to 73.6% in Ta-Kuk) except for Wan-Pro due to no vitamin C being detected in the previous study (Charoenkiatkul et al., 2012). After cooking, the amount of vitamin C probably decreased due to its instability at high temperatures (Oboh, 2005).

The highest macro mineral content was potassium, ranging from 231 to 560 mg/100 g FW, with the highest being contained in the shoots and young leaves of Jang. All indigenous plant samples also provided calcium and phosphorus (39–186 and 31–137 mg/100 g FW, respectively), but only a small amount of magnesium (21–62 mg/100 g FW) and sodium (<40 mg/100 g FW), which were mainly found in the shoots and young leaves of Pak-Wan-Pa. Consistent with previous studies, Pak-Wan-Pa was high in vitamin C, phosphorus, and calcium [99, 133, and 108 mg/100 g FW, respectively (Charoenkiatkul et al., 2012); 83.6, 68, and 24 mg/100 g FW, respectively (Somsub et al., 2008)]. For trace elements, all indigenous plant samples contained iron, copper, and zinc at <3 mg/100 g FW. The shoots and young leaves of Wan-Pro contained the highest amount of iron (2.79 mg/100 g FW), while Jang contained the highest amount of copper and zinc (0.30 and 1.41 mg/100 g FW, respectively). After cooking, the amount of minerals in most vegetables significantly decreased ($p \leq 0.05$) probably due to their migrating into the boiling water (Oboh, 2005). Shoots and young leaves of Jang have a major characteristic being consumed as softened leaves as opposed to other vegetables which may play a role in loss of several minerals (63.6% for K, 54.8% for Mg, 50.0% for Cu, 47.9% for Ca, 43.3% for Zn, 25.2% for Fe and 22.8% for P).

TABLE 3 Vitamin C and minerals in the indigenous plants (per 100 g fresh weight, $N = 3$).

Sample name	Vitamin C (mg)	Calcium (mg)	Phosphorus (mg)	Magnesium (mg)	Sodium (mg)	Potassium (mg)	Iron (mg)	Copper (mg)	Zinc (mg)
Jang, fresh	126 ± 7	121 ± 86	101 ± 3	31 ± 3	25 ± 9	560 ± 12	1.19 ± 0.17	0.30 ± 0.05	1.41 ± 0.25
Jang, blanch	82 ± 20*	63 ± 37*	78 ± 9*	14 ± 2*	24 ± 10	204 ± 51*	0.89 ± 0.21*	0.15 ± 0.01*	0.80 ± 0.14*
Pak-Wan-Pa, fresh	146 ± 19	186 ± 42	137 ± 11	62 ± 6	37 ± 11	432 ± 23	0.85 ± 0.13	0.22 ± 0.01	0.93 ± 0.12
Pak-Wan-Pa, boil	52 ± 7*	203 ± 48*	111 ± 8*	46 ± 9*	13 ± 3*	186 ± 20*	1.18 ± 0.10*	0.18 ± 0.01*	0.81 ± 0.07
Ta-Kuk, fresh	212 ± 32	39 ± 8	110 ± 7	56 ± 3	11 ± 2	299 ± 25	1.5 ± 0.06	0.19 ± 0.04	0.78 ± 0.13
Ta-Kuk, boil	56 ± 9*	38 ± 9	89 ± 21*	35 ± 3*	9 ± 4	118 ± 9*	1.3 ± 0.21	0.12 ± 0.00*	0.37 ± 0.03*
Wan-Pro, fresh	2 ± 0	53 ± 7	35 ± 2	24 ± 6	11 ± 2	372 ± 28	2.79 ± 0.36	0.03 ± 0.01	0.24 ± 0.06
Wan-Pro, blanch	3 ± 1	53 ± 9	27 ± 1*	21 ± 5	8 ± 2	244 ± 7*	1.91 ± 0.47*	0.02 ± 0.01	0.17 ± 0.04*
Som-Kob, fresh	10 ± 1	103 ± 3	32 ± 1	34 ± 2	7 ± 2	231 ± 6	1.32 ± 0.03	0.13 ± 0.01	0.34 ± 0.03
Som-Kob, blanch	5 ± 1*	95 ± 10	38 ± 3*	26 ± 1*	8 ± 1	150 ± 13*	0.93 ± 0.04*	0.11 ± 0.01	0.29 ± 0.01*
Ka-Tur, fresh ($N = 1$)	2	38	31	22	23	370	1.09	0.04	0.36
Ka-Tur, boil ($N = 1$)	2	31	24	15	10	238	0.94	0.02	0.27

*Values of each parameter in cooked vegetables were significantly different for a given variable ($p < 0.05$ paired sample t-test) compared to those of each fresh vegetable.

TABLE 4 Bioactive compounds and antioxidant activities of the indigenous plants (per 100 g fresh weight, $N = 3$).

Sample name	Lutein (mg)	Zeaxanthin (mg)	β-cryptoxanthin (mg)	α-carotene (mg)	β-carotene (mg)	Total Carotenoids (mg)	Total polyphenol (mgGAE)	Total antioxidant activity (μmolTE)
Jang, fresh	nd	nd	nd	2.2 ± 0.4	7.7 ± 2.5	9.9 ± 3.0	2,816 ± 677	16,2478 ± 36809
Jang, blanch	nd	nd	nd	6.0 ± 1.8*	19.5 ± 5.8*	25.5 ± 7.6*	1,528 ± 512*	111,450 ± 31,204*
Pak-Wan-Pa, fresh	nd	nd	3.0 ± 1.0	4.0 ± 2.2	21.0 ± 5.5	28.0 ± 8.7	292 ± 86	10,643 ± 1,721
Pak-Wan-Pa, boil	nd	nd	2.7 ± 0.2	2.3 ± 0.7*	12.5 ± 2.6*	17.4 ± 3.4*	141 ± 10*	5,598 ± 1,466*
Ta-Kuk, fresh	nd	nd	nd	5.6 ± 0.4	37.2 ± 5.7	42.8 ± 5.6	383 ± 61	16,022 ± 2,410
Ta-Kuk, boil	nd	nd	nd	10.6 ± 2.3*	55.6 ± 14.3*	66.2 ± 13.4*	150 ± 13*	5,905 ± 673*
Wan-Pro, fresh	nd	nd	nd	69.2 ± 14.5	73.7 ± 14.5	142.9 ± 28.2	77 ± 3	3,134 ± 567
Wan-Pro, blanch	nd	nd	nd	92.0 ± 8.7*	83.3 ± 8.4*	175.3 ± 16.8*	65 ± 5*	2,564 ± 392*
Som-Kob, fresh	nd	nd	nd	11.5 ± 3.1	18.9 ± 1.2	32.2 ± 7.5	120 ± 4	8,206 ± 1,142
Som-Kob, blanch	nd	nd	nd	18.9 ± 1.2*	23.2 ± 1.1*	42.1 ± 2.3*	767 ± 30*	24,067 ± 868*
Ka-Pee-Jun, fresh ($N = 1$)	nd	nd	nd	5.6 ± 0.5	21.2 ± 3.2	26.7 ± 3.5	384 ± 33	5,831 ± 727
Pak-God, fresh ($N = 1$)	nd	nd	nd	3.4 ± 0.1	16.6 ± 1.1	20.0 ± 1.1	129 ± 1	1,159 ± 51
Pak-God, blanch ($N = 1$)	nd	nd	nd	1.5 ± 0.1	8.9 ± 0.4	10.4 ± 0.4	159 ± 3	5,524 ± 85
Ka-Tur, fresh ($N = 1$)	nd	nd	nd	0.7	1.3	2.0	93	1,727
Ka-Tur, boil ($N = 1$)	nd	nd	nd	3.7	10.2	13.9	63	1,332

nd, not detected due to less than detection limit.
*Values of each parameter in cooked vegetables were significantly different for a given variable ($p < 0.05$ paired sample t-test) compared to those of each fresh vegetable.

Carotenoid contents

Carotenoid contents of the eight indigenous plant varieties are shown in Table 4 below. The highest total carotenoid contents were found in the shoots and young leaves of Wan-Pro, followed by Ta-Kuk, Som-Kob, Pak-Wan-Pa (142.9, 42.8, 32.2, 28.0 mg/100 g FW, respectively) (Figure 3), while the lowest was in the flowers of Ka-Tur (2.0 mg/100 g FW). The carotenoid contents of indigenous plants in this study were significantly higher ($p \geq 0.05$) than in the original previous study (Charoenkiatkul et al., 2012), such as Pak-Wan-Pa (28 vs. 5.4 g/100g), Ta-Kuk (1.97 vs. 0.72 g/100 g), Wan-Pro (142.9 vs. 3.8 g/100 g), and Ka-Tur (1.97 vs. 0.72 g/100 g). All indigenous plant varieties contained predominantly β-carotene (55–89%), followed by α-carotene (10–45%), except for Wan-Pro which contained α-carotene (51–54%) followed by β-carotene (46–49%). Lutein, zeathantin, and β-cryptoxanthin were not detected in all plants in this study, except for Pak-Wan-Pa where β-cryptoxanthin was detected at 3 mg/100 g FW. Comparing carotenoid content between cooked and raw plant, the carotenoid contents of the cooked plant samples were significantly higher ($p \leq 0.05$) than that of the corresponding raw samples, except for Pak-Wan-Pa and Pak-God. Thermal food processes, such as boiling and blanching, can cause partial degradation of carotenoid pigments and promote isomerization of β-carotene content in the samples (Bernhardt and Schlich, 2006; D'evoli et al., 2013).

Total phenolic contents

Total phenolic contents of the eight indigenous plant varieties varied widely, ranging from 77 to 2816 mg GAE/ 100 g FW as shown in Table 4 below. Shoots and young leaves of Jang had the highest total phenolic contents, followed by Ta-Kuk and Pak-Wan-Pa (2816, 383, 292 mg GAE/ 100 g FW, respectively), and the lowest content was in Wan-Pro (77 mg GAE/ 100 g FW). The wide variation in total polyphenol contents in plants might occur from the variety of the plant, stage of ripening, climate conditions, sample collection, transportation, and sample preparation (Rop et al., 2011). Comparison of total phenolic contents of some indigenous plants in this study, such as Pak-Wan-Pa and Ta-Kuk, with results of previous studies indicate similar contents, i.e., Pak-Wan-Pa from Saraburi and Uthai Thani provinces (296.44 and 265.63 mg GAE/100 g, respectively) (Charoenchai et al., 2015), Pak-Wan-Pa and Ta-Kuk from Kanchanaburi province (296 and 451 mg GAE/100 g, respectively) (Charoenkiatkul et al., 2012).

Antioxidant activities

The results of antioxidant activities as measured by ORAC assay were accordance with the result of total phenolic contents, which are shown in Table 4 below. The shoots and young leaves of Jang (162,478 μmol TE/100 g FW), Ta-Kuk (16,022 μmol

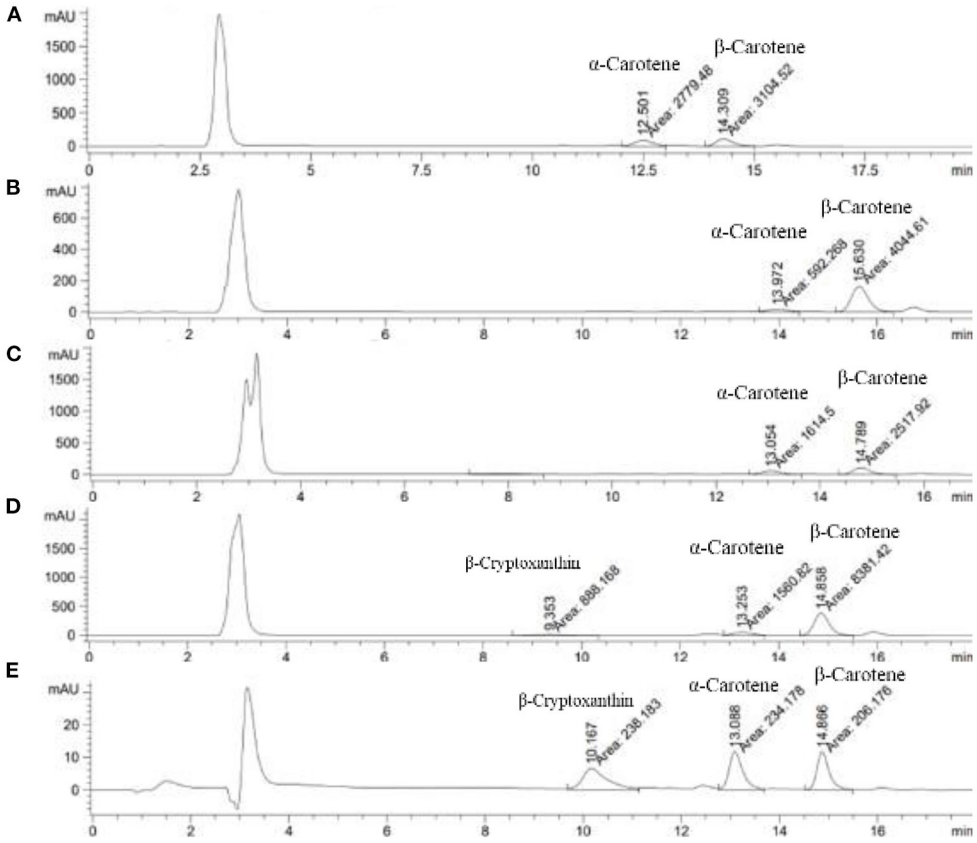

FIGURE 3
Chromatogram of identifying the peaks of carotenoid compounds of Wan-Pro **(A)**, Ta-Kuk **(B)**, Som-Kob **(C)**, Pak-Wan-Pa **(D)**, Standard carotenoids **(E)**.

TE/100 g FW), and Pak-Wan-Pa (10,643 μmol TE/100 g FW) had the greatest ORAC values, while the lowest was in Wan-Pro (3,134 μmol TE/100 g FW). A strong consistency between total phenolic content and ORAC values was observed in many other studies, which confirmed that phenolic was the major contributor to antioxidant activities (Maisuthisakul and Suttajit, 2007; Han and Yang, 2008; Maisuthisakul and Pasuk, 2008). ORAC values in this study were less than those previously reported (Charoenkiatkul et al., 2012), but there were no significant differences ($p \geq 0.05$), such as Pak-Wan-Pa (10,643 vs. 8,000 μmol TE/100 g FW), Ta-Kuk (16,022 vs. 14,400 μmol TE/100 g FW), Wan-Pro (3,134 vs. 3,800 μmol TE/100 g FW), and Ka-Tur (1,727 vs. 1,400 μmol TE/100 g FW), respectively.

True retention

The percentage true retention (%TR) of nutrients in the cooked processes is presented in Table 5 below. The retention of protein, dietary fiber, and minerals (calcium, phosphorus, magnesium, iron, copper, and zinc) were almost wholly retained (closed to 100%TR), while potassium was the least retained (49.9–77.10%TR). Blanched plants retained higher concentrations of vitamin C than those that had been boiled (97.8–109.8 and 35.8–42.5%TR for blanching and boiling, respectively). Vitamin C retention in cooked vegetables in a previous study ranged from 34.1 to 79.4% among the various vegetables and cooking methods, but was the least in boiling (Mellova et al., 1996). This result was consistent with the lowest vitamin C retention values shown in the boiling of spinach (33.9%TR) and green beans (63.7%TR) (Warthesen et al., 1984). The main mechanisms of vitamin C loss appear to be due to the vitamin's water solubility and sensitivity to temperature, so it is easily degraded during cooking. Elevated temperatures and long cooking times have been found to cause particularly severe losses of vitamin C (Rumm-Kreuter and Demmel, 1990; Oboh, 2005; Tian et al., 2016). The retention of total polyphenol and antioxidant in this study's boiled plants (52.6 and 50.0%TR in Ta-Kuk, 60.0 and 62.5%TR in Pak-Wan-Pa, respectively) was lower than in blanched plants (81.7 and 102.0% TR in Jang, 98.1 and 96.2% TR in Wan-Pro, respectively). The retention of carotenoids increased in boiled or blanched plants (>100%TR),

TABLE 5 Percentage true retention for the cooking methods of indigenous plants ($N = 3$).

	Jang, blanch	Pak-Wan-Pa, boil	Ta-Kuk, boil	Wan-Pro, blanch	Ka-Tur, boil ($N = 1$)	Som-Kob, blanch
Protein	90.8 ± 4.7	114.1 ± 15.0	102.8 ± 3.4	102.7 ± 10.3	89.0	109.4 ± 6.2
Dietary fiber	102.7 ± 11.3	143.8 ± 16.2	127.6 ± 4.6	106.3 ± 1.5	97.8	108.8 ± 6.1
Calcium	84.5 ± 9.3	126.3 ± 15.9	131.8 ± 6.3	115.5 ± 9.0	97.2	111.0 ± 6.3
Phosphorus	117.2 ± 12.7	94.0 ± 7.2	107.4 ± 22.4	90.2 ± 2.1	93.2	111.5 ± 6.3
Magnesium	66.4 ± 2.1	86.4 ± 16.1	83.4 ± 13.0	103.6 ± 20.9	84.5	109.7 ± 6.2
Sodium	83.4 ± 2.9	43.9 ± 21.0	102.8 ± 39.1	90.6 ± 43.1	49.2	104.9 ± 5.9
Potassium	54.7 ± 10.6	49.9 ± 6.2	59.9 ± 0.8	77.1 ± 4.2	77.1	111.1 ± 6.3
Iron	111.6 ± 12.9	163.3 ± 26.5	115.3 ± 16.5	79.7 ± 15.3	102.6	108.5 ± 6.1
Copper	79.1 ± 9.0	95.8 ± 15.5	89.2 ± 16.0	84.7 ± 30.3	59.8	109.9 ± 6.2
Zinc	85.6 ± 5.9	103.7 ± 12.6	64.1 ± 6.8	84.0 ± 13.4	89.3	107.8 ± 6.1
Vitamin C	97.8 ± 14.3	42.5 ± 13.7	35.8 ± 9.7	107.8 ± 18.3	101.4	109.8 ± 6.2
Total polyphenol	81.7 ± 16.0	60.0 ± 18.8	52.6 ± 3.8	98.1 ± 4.7	81.4	111.3 ± 6.3
Total antioxidant activity	102.0 ± 7.1	62.5 ± 23.0	50.0 ± 10.4	96.2 ± 5.4	92.3	110.2 ± 6.2
Carotenoids	398.6 ± 73.2	74.3 ± 7.6	209.6 ± 54.7	145.7 ± 14.6	843.2	108.6 ± 6.1

except for Pak-Wan-Pa (74.3%TR). A previous study of cooked vegetables showed β-carotene retention was in the range of 40.02–125.37% (Lee et al., 2018). Carotenoids extractability may be influenced by cooking. Additionally, the difference in the retention of carotenoids in cooked plants might be attributed to the loss of carotene caused by dripping during the cooking process (Bureau et al., 2015).

Conclusion

Nutrients, bioactive compounds, as well as antioxidant activities and carotenoid contents of eight commonly consumed indigenous plants in the conservation area were analyzed. The major nutrients found in all of the study's indigenous plants were protein and dietary fiber, while there were low levels of available carbohydrate and fat. The highest macro mineral content in all of the plants was potassium, followed by calcium and phosphorus. However, only small amounts of magnesium and sodium were evident. Trace elements found in small amounts in all of the plants were iron, copper, and zinc. The shoots and young leaves of fresh Ta-Kuk and Pak-Wan-Pa contained high level of vitamin C however it dramatically lost after cooking. Antioxidant activity in all of the plants was in accordance with phenolic compounds. Greater retentions of vitamin C, phenolic contents, and antioxidant activities were achieved by blanching compared to boiling, while retention of carotenoids increased when boiled or blanched. Shoots and young leaves of three indigenous plants [Jang (*Maerua siamensis* (Kurz), Ta-Kuk (*Albizia lebbeck* (L.) Benth), and Pak-Wan-Pa (*Melientha suavis* Pierre)] showed the greatest amounts of nutrients, bioactive compounds, and antioxidant activity which are recommended for consumption and promotion.

The data generated from this study are important for highlighting the nutritional value of these indigenous plants, their potential role in different food products, and their wider application for the food system overall. As such, the conservation of these indigenous plants should be a major food security concern and initiative. Sustainable extensive cultivation should also be undertaken to increase availability and diversity of the foods for community consumption. Further studies on health promotion and disease prevention as well as development of value-added products for trade should be undertaken.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

KJ and NS contributed to the conception and design of the study. PS, PK, NS, MS, and KJ did the survey and collect all samples in the conservation areas. PS and CC analyzed nutritive values and bioactive compounds. PK, CC, and KJ performed the statistical analysis and wrote a draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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