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Antioxidant Capacity and Antimutagenicity of Thermal Processed Thai Foods

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Abstract

Ten different foods containing local Thai vegetables were selected to study their antioxidant and antimutagenic properties. The antioxidant capacity, antimutagenicity, and total phenolic content of methanol extracts obtained from cooked food samples exhibited a wide variation ranging from 24-140 mg vitamin C equivalent/100 g, 53-93% and 35-125 mg gallic acid equivalent/100 g. The three foods highest in antioxidant capacity were Kaeng Hoi Bai Chaplu (wild betal curry), Phat Sator (stir-fried petai beans), and Kaeng Pa Gai (mixed vegetables curry). The foods that exhibited an antimutagenicity greater than 85% were Tomkathi Saibua (water lily stalk curry), Kaeng Pa Gai, Kaeng Taipla (southern curry), and Kaeng Lueang Khun (giant taro stem curry). Next, aiming to develop retort pouch food products, the effect of sterilization heat (121°C) on four selected foods was studied. Antioxidant capacity, antimutagenicity, and total phenolic content increased by 0-120%, 13-40%, and 6-54% after sterilization, respectively.

Discipline: Food

Additional key words: total phenolics, DPPH scavenging capacity, Ames test, processed food, retort food

Introduction

The role of free radicals in many diseases has been well established. The harm caused by free radicals, however, can be blocked by antioxidant substances, which scavenge for free radicals and detoxify the organism. A wide range of phenolics derived from herbs and spices possesses potent antioxidant, anti-inflammatory, antimutagenic, anticarcinogenic, and anti-tumor properties, which contribute to their chemopreventive potential (Surh, 2002).

In Southeast Asia, many kinds of plants are sold as vegetables in markets. Many of them are common in the region, such as *Polygonum odoratum*, *Morinda citrifolia*, *Parkia speciosa*, *Melientha suavis*, *Sauropus androgynus*, and *Piper sarmentosum*. It is documented that about 250 species of plants are used as vegetables in Thai cuisine (Prachasaisoradech, 1999). These vegetables are either served raw or cooked by boiling, steaming, frying, or grilling. Foods using local vegetables in either a plain soup or chili-based curry (Kaeng in Thai) are common in this region. Most of them contain combinations of herbs and vegetables.

Local Thai foods are of interest to health-conscious consumers due to their use of vegetables, herbs, and spices. Their potential antioxidant capacity on peroxide radicals and the antimutagenicity of around 200 kinds of fresh local vegetables have been investigated (Nakahara & Trakoontivakorn, 1999; Nakahara *et al*., 2002). In Thailand, each region (the northern, northeastern, central, and southern area) has its own local foods that use local vegetables as their main ingredients. In the previous study, we demonstrated that northern and northeast-

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ern Thai foods containing local vegetables exhibited a high antioxidant capacity. The antioxidant capacity of methanol extracts obtained from 100 g foods was between 13-86 mg vitamin C equivalent (VCE) in 10 kinds of northern Thai foods and 4-176 mg VCE in 10 kinds of northeastern Thai foods (Tangkanakul *et al*., 2006).

For this paper, we extended our study to the antioxidant capacity and antimutagenicity of local foods from central and southern Thailand. The major vegetable ingredients of the 10 selected foods were cowa, wild betal, water mimosa, noni leaf, water lily stalk, nitta sprout, and petai bean. In addition, the effects of thermal processing (sterilization) on the antioxidant capacity and antimutagenicity of four of the selected foods were studied in order to develop retort pouch food products in a stand-up laminated aluminum foil bag format.

Materials and methods

1. Materials

1,1-diphenyl-2-picrylhydrazyl radical (DPPH) was purchased from Sigma. Mutagen, Trp-P-1 (3-amino-1,4-dimethyl-5*H*-pyrido[*4,3-b*]indole) was a product of Wako Pure Chemical (Osaka, Japan). S9 mix from the livers of drug-treated Sprague-Dawley rats (male) for the Ames test was purchased from Kikkoman (Noda, Japan). L-Histidine and D-biotin were obtained from BDH Laboratory. All other chemicals used were of analytical grade. Vegetables, herbs, and spices were purchased from local markets in Bangkok, Thailand. They were obtained on the preparation days, except for some of the common spices: garlic, shallots, and dried chili.

2. Preparation of Foods

Ten of commonly consumed foods in central and southern Thailand that contain indigenous vegetables as their major ingredients were selected for this study. All the foods were prepared according to their original recipes. They were Kaeng Pa Gai (KPG, soup, no coconut milk, contains various kinds of vegetables), Kaengsom Phak Krachet (KPK, soup, contains water mimosa), Tomkathi Saibua (TS, soup with coconut milk, contains water lily stalk), Kaeng Mu Chamuang (KMC, soup, contains cowa leaves), Kaeng Om Pladuk Bai Yor (KOPBY, soup with coconut milk, contains noni leaves), Kaeng Taipla (KT, soup, contains various kind of vegetables), Kaeng Luk Riang Mu (KLRM, soup with coconut milk, contains nitta sprout), Kaeng Lueang Khun (KLK, soup, contains giant taro stem), Kaeng Hoi Bai Chaplu (KHBC, soup with coconut milk, contains wild betal leaves), and Phat Sator (PS, stir-fried petai bean). KPG, KPK, TS, KMC, and KOPBY are from central Thailand, and KT, KLRM, KLK, KHBC, and PS are from southern Thailand. The inedible portions, such as fish bone, were removed, then homogenized and kept in a freezer (-20°C) for further analysis.

Four of the 10 selected foods were further developed into ready-to-eat products: KPG, TS, KOPBY, and KT. The foods were packed in a stand-up laminated aluminum pouch (PET12/NY15/AL 9/CPP80, 120x180x35 mm.), sealed with HENKOVAC, and sterilized by hot water spray retort (HISAKA, Model RCS-60 SPXTG) at 121°C for 25-30 min.

The effects of thermal processing on the antioxidant capacity, total phenolic content, and antimutagenicity of the products were studied by sampling the product in the pouches before and after the sterilization process and keeping them at -20°C for analysis.

The vegetables, herbs, and spices used to prepare the foods, together with their botanical names, are listed in Table 1. The ingredients in each recipe are given in Table 2.

3. Sample Extraction

Samples were extracted in 100% methanol at room temperature. The extracting ratio of sample to methanol was 1:10 (w/v) for the raw ingredients and 1:5 (w/v) for the homogenized foods. The supernatants were stored in capped bottles and kept at -20°C until further use to determine antioxidant capacity, antimutagenicity, and total phenolic content.

4. Antioxidant capacity assay

DPPH scavenging activity was determined according to a method of Ohnishi *et al*. (1994). DPPH %scavenging activity (%SA) was calculated from the equation (1-X/C)*100, where X is the absorbance of the extract and C is the absorbance of the control. Vitamin C (ascorbic acid, Fisher Scientific) was used as the standard, and the antioxidant capacity was expressed as g or mg vitamin C equivalent (VCE)/100 g fresh weight.

5. Antimutagenicity assay

The antimutagenic effect of plant or food extracts against Trp-P-1 in *Salmonella typhimurium* TA98 was assayed by the Ames preincubation method using S9 mix as explained by Trakoontivakorn *et al*. (1999). Briefly described, the assay mixture contained Trp-P-1 (50 ng in 50 µl of DMSO), 50 µl of S9 mix, 0.7 ml of 0.1 M potassium phosphate buffer (pH 7.0), 50 µl of sample extract, and bacterial culture (0.1 ml). The mixture was incubated for 20 min at 37 °C. Antimutagenic activity was evaluated with a decrease in the number of His+ revertant by sample extracts.

6. Determination of Total Phenolic Content

Total phenolic content was determined using the Folin-Ciocalteau reagent, adapted from Singleton & Rossi (1965). Gallic acid was used as standard. The results were expressed as g or mg gallic acid equivalent (GAE)/ 100 g fresh weight.

7. HPLC analysis

An HPLC system comprising a vacuum degasser, quaternary pump, autosampler, thermostated column compartment, and UV detector was used. A 100 mm x 4.6 mm i.d. TSKgel Super-ODS (TOSOH Co.) was maintained at 40°C. The analytical condition was monitored through a linear gradient using 5% formic acid and acetonitrile from 10% to 70% for 30 min, eluted at a flow rate of 1ml/min and detected at 280 nm.

Results and discussion

1. Antioxidant Capacity and Antimutagenicity of Plant Ingredients

The antioxidant capacity and total phenolic content were determined for the methanol extracts prepared from the 23 plant samples (10 vegetables, 13 herbs or spices) that are the major ingredients of the selected Thai foods (Table 1). A high positive correlation (R= 0.94) was observed between total phenolic content and antioxidant capacity in the tested plant extracts. This result agrees with previous studies on the antioxidant activity and total phenolic content of fruits, vegetables, herbs, and spices (Vinson *et al*., 1998; Velioglu *et al*., 1998; Nuutila *et al*., 2003). Among the 23 plant extracts, turmeric, pea eggplant, and young pepper showed remarkably high antioxidant capacity (0.79-1.04 g VCE/100 g) and total phenolic content

Table 1. Antioxidant capacity, total phenolic content, and antimutagenic activity of vegetables on a fresh weight basis

Sample	Antioxidant capacity (g VCE[1]/100 g)	Total phenolic content (g GAE[2]/100 g)	Antimutagenicity (% Inhibition)
Vegetables			
Pea eggplant (*Solanum torvum*)	0.86	1.32	71
Cowa (*Garcinia cowa*)	0.21	0.70	67
Wild betal (*Piper sarmentosum*)	0.19	0.74	93
Water mimosa (*Neptunia oleracea*)	0.15	0.55	57
Noni leaf (*Morinda citrifolia*)	0.13	0.44	58
Water lily stalk (*Nimphaea lotus*)	0.08	0.10	33
Wing bean (*Psophocarpus tetragonolobus*)	0.06	0.14	67
Nitta sprout (*Parkia timoriana*)	0.04	0.13	10
Petai bean (*Parkia speciosa*)	0.04	0.12	31
Giant taro stem (*Colocasia gigantea*)	0.01	0.03	40
Herbs and spices			
Turmeric (*Curcuma longa*)	1.04	2.86	92
Young pepper (*Piper nigrum*)	0.79	1.66	74
Holy basil (*Ocimum tenuiflorum*)	0.25	0.55	50
Bird chili (*Capsicum frutescens* var. frutescens)	0.15	0.64	58
Galangal (*Alpinia galangal*)	0.10	0.22	97
Lemongrass (*Cymbopogon citratus*)	0.12	0.15	96
Coriander seed (*Coriandrum sativum*)	0.10	0.14	ND
Kaffir lime leaf (*Citrus hystrix*)	0.08	0.71	87
Fingerroot (*Boesenbergia pandurata*)	0.06	0.21	74
Chilli (*Capsicum annuum* var. acuminatum)	0.05	0.20	59
Shallot (*Allium ascalonicum*)	0.01	0.16	50
Garlic (*Allium sativum*)	0.01	0.08	58
Tamarind, paste (*Tamarindus indica*)	0.01	0.02	ND

[1] : vitamin C equivalent, [2] : gallic acid equivalent, ND = not determined.

(1.32-2.86 g GAE/100 g). Other notable vegetables showing moderate antioxidant capacity were cowa, wild betal, water mimosa, and noni leaves. These vegetables could supply a considerable amount of antioxidants to humans because large amounts of these vegetables can be consumed in one meal.

Mutagenic assays, such as the Ames test, have been widely used to assess the antimutagenic and anticarcinogenic properties of various compounds (Ikken *et al*., 1999). The antimutagenicity of vegetable extracts against Trp-P-1 was evaluated by the Ames test. The vegetable extracts exhibited an antimutagenicity ranging from weak to strong depending on the type of vegetable (Table 1). The results showed that galangal, lemongrass, wild betal, turmeric, and kaffir lime leaf possessed a strong antimutagenicity ranging from 87-97%, followed by

Table 2. List of ingredients in selected central and southern Thai foods. The proportion of major ingredients is calculated based on weight

Foods	Major ingredients (%)	Vegetables, herbs and spices (%)
Kaeng Pa Gai (KPG)	garlic (2.0), shallot (1.3), chilli (2.8), lemon grass (1.3), galangal (0.8), fingerroot (3.6), kaffir lime peels (0.2), coriander root (0.3), pepper (1.2), coriander seeds (0.1), bamboo shoot (7.1), baby corn (5.1), winged beans (4.1), pea eggplant (3.6), holy basil (1.8), kaffir lime leaves (0.2), chicken meat (17.8), fish sauce (2.8), sugar palm (0.5), salt (0.3), shrimp paste (0.5),vegetable oil (2.0), water (40.8)	35.5
Kaengsom Phak Krachet (KPK)	water mimosa (23.1), shallot (3.8), fingerroot (0.8), dried chilli (0.8), salt (0.4), shrimp paste (0.4), fish meat (1.9), tamarind paste (7.7), palm sugar (3.8), fish sauce (3.1), salt (0.4), water (53.8)	28.5
Tomkathi Saibua (TS)	water lily stalk (27.6), shallot (5.5), pepper (0.3), shrimp paste (0.7), salt (0.8), steamed shot bodied mackerel (13.8), coconut milk (27.6), palm sugar (4.8), tamarind paste (4.8), water (14.1)	38.2
Kaeng Mu Chamuang (KMC)	cowa leaves (4.7), shallot (2.3), garlic (2.3), galangal (1.2), lemon grass (1.4), coriander root (0.9), dried chilli (0.5), dried shrimp (0.5), shrimp paste (0.7), salt (0.2), pork belly (11.7), pork (11.7), soy sauce (0.1), vegetable oil (1.4), palm sugar (4.7), fish sauce (1.9), water (53.8)	13.3
Kaeng Om Pladuk Bai Yor (KOPBY)	noni leaves (14.5), garlic (1.7), shallot (2.0), lemon grass (0.6), galangal (0.3), coriander roots (0.6), fingerroot (0.9), kaffir lime peels (0.1), salt (0.3), pepper (0.1), dried chilli (0.6), shrimp paste (0.3) catfish (17.4), coconut milk (40.5), fish sauce (2.3), palm sugar (0.5), water (17.3)	21.4
Kaeng Taipla (KT)	fermented fish viscera (6.4), garlic (4.3), shallot (2.1), lemon grass (1.3), galangal (0.4), kaffir lime peels (0.2), chilli (1.7), pepper (0.1), shrimp paste (1.4), turmeric (0.2), kaffir lime leaves (0.5), bamboo shoot (14.2), pea eggplant (5.3), cashew nut (5.3), tamarind paste (2.1), palm sugar (0.7), grilled fish (7.1), water (46.7)	37.7
Kaeng Luk Riang Mu (KLRM)	nitta sprout (22.5), garlic (1.7), shallot (1.1), lemon grass (0.8), galangal (0.3), chilli (1.4), pepper (0.1), shrimp paste (0.8), tumeric (0.6), salt (0.3), pork (22.5), coconut milk (25.3), fish sauce (2.2), palm sugar (0.8), water (19.6)	28.5
Kaeng Lueang Khun (KLK)	giant taro stem (28.5), garlic (1.9), lemon grass (0.5), galangal (0.1), shrimp paste(0.7), chilli (1.5), salt (0.4), turmeric (0.3), fish (12.8), tamarind paste (4.3), fish sauce (3.3), palm sugar (1.4), lime juice (1.4), water (42.8)	37.1
Kaeng Hoi Bai Chaplu (KHBC)	wild betal leaves (14.3), blood cockle (23.9), garlic (2.4), shallot (2.0), lemon grass(1.6), galangal (0.5), turmeric (0.5), shrimp paste (2.0), salt (0.4), pepper (0.1), dried chilli (0.8), coconut milk (33.8), fish sauce (1.2), palm sugar (0.6), water (15.9)	22.2
Phat Sator (PS)	petai beans (37.2), garlic (3.7), chilli (3.3), shrimp paste (2.2), prawn (14.9), minced pork (14.9), vegetable oil (3.0), soy sauce (1.8), fish sauce (1.8), palm sugar (1.5), lime juice (0.7), water (14.9)	44.2

young pepper, fingerroot, pea eggplant, cowa, and wing bean showing moderate inhibition (67-74%). Many of the plants mentioned above were previously reported to possess antimutagenicity (Vinitketkumnuen *et al*., 1994; Trakoontivakorn *et al*., 1999; Nakahara *et al*., 2002). Pea eggplant contains chlorogenic acid as the dominant phenolic component, accounting for more than 75% of its total phenolic content (data not shown), like other varieties of eggplant (Luthria & Mukhopadhyay, 2006). Since many polyphenols including chlorogenic acid act as potent antimutagenic agents (Bu-Abbas *et al*., 1994), chlorogenic acid largely contributes to the total antimutagenicity of pea eggplant. Nitta sprout, noni leaf, and water mimosa possessed relatively high in phenolic content: 0.13, 0.44 and 0.55 g GAE/100 g; however, they demonstrated low antimutagenicity as shown in Table 1.

2. Antioxidant Capacity of 10 Selected Foods

Plant content in the studied foods ranged from 13% in KMC (cowa leaves curry) to 44% in PS (stir-fried petai bean). Plants included vegetables, herbs, and spices (Table 2). The percentage of plants was within the range present in northern and northeastern Thai foods: 11-72% as reported in our previous study (Tangkanakul *et al*., 2006).

The antioxidant capacity and total phenolic content of 10 selected foods are shown in Table 3. These foods exhibited a wide variation in antioxidant capacity, ranging from 24-140 mg VCE/100 g. Three foods showed comparatively high antioxidant capacity: KHBC (wild betal curry), 140 mgVCE/100 g, PS, 140 mg VCE/100 g; and KPG (mixed vegetable curry), 138 mgVCE/100 g. The exhibited antioxidant activity corresponded to their high phenolic content, except for PS. The ingredients with high antioxidant capacity in KHBC are turmeric, pepper, and wild betal leaves. Those in KPG are pea eggplants, holy basil, young pepper, and kaffir lime leaves. The PS recipe used in this study contained as much as 37% petai beans and 7% other plant materials. The antioxidant capacity of fresh petai beans was quite low, only 0.04 g VCE/100 g. The high antioxidant capacity of PS was obviously induced by heat. There is currently no information about the effect of heat on the antioxidant activity of petai beans. However, heat from boiling, steaming, and microwaving could increase antioxidant activity as discovered in pepper, broccoli, spinach, and green beans (Turkmen *et al*., 2005).

Other foods in this study, which possess moderate antioxidant capacity, were KPK (water mimosa curry), KLRM (nitta sprout curry), and KMC, ranging from 62-81 mg VCE/100 g. The other foods had an antioxidant capacity in the failing range of 24-49 mg VCE/100 g. Among the 30 studied foods, 20 from the previous study (Tangkanakul *et al*., 2006), most foods had an antioxidant capacity in the range of 30-55 mg VCE/100 g.

It has been found that polyphenols are one of the most effective antioxidative constituents in plant foods, including fruits, vegetables, and grains (Velioglu *et al*., 1998). Hence it is important to quantify polyphenolic content and to assess their contribution to antioxidant activity.

The correlation between the total phenolic content and antioxidant capacity of 10 selected foods is shown in Fig. 1. The results show a positive linear correlation between the total phenolic content and antioxidant capacity of the selected foods from central Thailand (R = 0.95). However, a low correlation is illustrated in the selected foods from southern Thailand (R = 0.62). Our previous study on northern and northeastern Thai foods containing vegetables demonstrated a high correlation between total phenolic content and antioxidant capacity (Tangkanakul *et al*., 2006). The foods from southern Thailand that showed a low relationship are KT and PS. KT contained high phenolic content but low antioxidant activity (Table 3). The phenolic content of KT had low antioxidant capacity. Inversely, PS showed high antioxidant activity, though the total phenolic content was not as high as expected. PS contained non-phenolic antioxidants or phenolic content with a high antioxidant capacity.

Table 3. Antioxidant capacity, total phenolic content in selected Thai foods and antimutagenic activity of food extracts against the mutagenesis induced by Trp-P-1 in *Salmonella typhimurium* TA 98

Foods	Antioxidant capacity (mg VCE/ 100 g food)	Total phenolic content (mg GAE/ 100 g food)	Antimutagenicity (%)
Central			
KPG	138	108	90
KPK	81	68	59
TS	32	35	93
KMC	62	72	71
KOPBY	48	62	77
Southern			
KT	49	101	86
KLRM	76	72	53
KLK	24	42	86
KHBC	140	125	70
PS	140	79	69

3. Antimutagenic Activity of 10 Tested Foods

The Ames test has been widely used to assess the antimutagenic and anticarcinogenic properties of various compounds. In our present study the antimutagenicity of food extracts against Trp-P-1 was evaluated by means of the Ames test. All the food extracts possessed an antimutagenicity that ranged from 53-93% inhibition (Table 3).

TS (water lily stalk curry) showed the strongest antimutagenicity. The major ingredient in TS is water lily stalk, at almost 30% (Table 2). The antimutagenicity of fresh water lily stalks is quite low: only 33%. Other possible sources of antimutagens in TS are shallot, pepper, and tamarind paste. However, their antimutagenicity is not very high (Table 1). Hence, active substances might be newly generated during cooking.

The antimutagenicity of KPG, KT (Southern curry soup), KLK (giant taro stem curry), and KOPBY (noni leaves curry) are considerably high: 77-90%. The strong antimutagenicity of these soups possibly comes from other ingredients such as galangal, lemongrass, turmeric, kaffir lime leaf, fingerroot, and pepper. It has been confirmed that the antimutagenic components of galangal and fingerroot did not change after heat treatment (Trakoontivakorn *et al*., 1999).

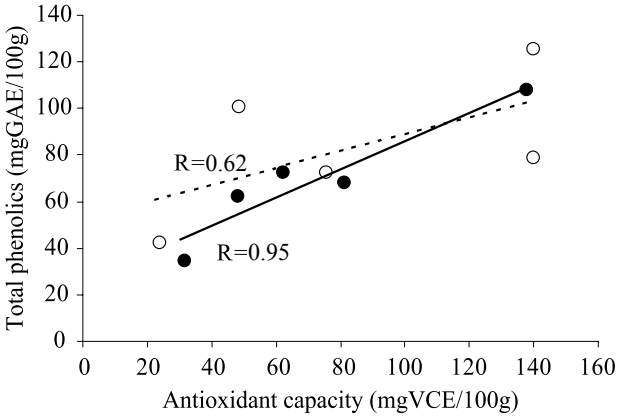

Fig. 1. Relationship between total phenolic content and antioxidant capacity of central and southern Thai foods

● : Central food, ○ : Southern food, ——— : Linear (Central food), - - - - - - - : Linear (Southern food)

4. Influence of Thermal Processing

KPG, TS, KOPBY, and KT were further studied to compare the antioxidant capacity and antimutagenicity of products before and after sterilization (Table 4). The antioxidant capacity of three processed foods, KPG, KT, and TS, were increased by 9%, 83%, and 120%, respectively, whereas the antioxidant capacity of KOPBY products was not affected by thermal processing. For TS, water lily stalk from two different sources was used, and they provided an antioxidant capacity of 58 and 75 mg VCE/100 g, respectively. After heating at 121°C for 25 min, the antioxidant capacity of TS products was enhanced by 94 and 138%, respectively, from those prior to heat. The increase in phenolic compounds after heat treatment in the TS products was up to 54% on average. This can be interpreted to mean that phenolic compounds were generated during the thermal process and they might have antioxidant capacity.

The HPLC chromatogram clearly demonstrated the changes in chemical composition in the methanol extract of the TS product (Fig 2). After the sterilization process, three new peaks (2 - 6 min) were formed and another peak (ca. 2.5 min) doubled in area, while the dominant peaks that eluted around 18 min became smaller. Compounds that have a higher polarity are generated by condensation or hydrolysis reactions from low-polarity compounds in the unheated sample during sterilization. This is similar to a study by Manzocco *et al*. (1998), which indicated that the pasteurization of tea extracts caused an increase in the antioxidant properties of teas. This was

Table 4. Antioxidant capacity, total phenolic content and antimutagenicity of processed foods before and after sterilization

Products	Antioxidant capacity (mg VCE/100 g food)			Total phenolic content (mg GAE/100 g food)			Antimutagenicity (%)		
	Before thermal process	After thermal process	Change (%)	Before thermal process	After thermal process	Change (%)	Before thermal process	After thermal process	Change (%)
KPG	79.1 [a]	86.4 [a]	9.3	117.1 [a]	132.7 [b]	13.3	68.8 [a]	77.5 [b]	12.6
TS	21.0 [a]	46.2 [b]	120.7	40.2 [a]	62.1 [b]	54.2	72.6 [a]	86.5 [b]	19.1
KOPBY	25.2 [a]	25.3 [a]	0.4	64.7 [a]	68.5 [a]	5.9	71.2 [a]	92.9 [b]	30.4
KT	43.7 [a]	79.8 [b]	82.6	133.0 [a]	182.0 [b]	36.9	65.2 [a]	90.6 [b]	38.9

Mean values in a row with different letter are significantly different at $p < 0.05$, according to Paired Student's t-test.

attributed to the formation of compounds that had antioxidant properties during heat treatment. A later study by Jiratanan & Liu (2004) showed that processed beets at 125°C could increase their total phenolic content by 14% as compared to the control.

In the KT retort product, a newly generated phenolic compound was detected with 37% increasing. It may contribute to the major increase in antioxidant capacity to 83%. The data in Table 4 confirmed that the phenolic compounds in KT displayed weak antioxidant property. Heat either in home or retort cooking did not destroy the antioxidative phenolic compounds.

Regarding antimutagenicity, all sterilized products exhibited inhibition ranging from 78-93% (Table 4). Among all the food products, KOPBY showed the highest antimutagenicity, whereas KPG had the lowest antimutagenicity at 78%. High thermal treatment was found to have a positive effect on the antimutagenicity of all products by increasing antimutagenicity 13-40%. However, the trends in antioxidant and antimutagenic activity were different. Thermal treatment greatly affected the antimutagenicity of KOPBY, whereas a small increase in antioxidant capacity and total phenolic content was observed. The antimutagenicity of TS only slightly increased in contrast to the tremendous increase in antioxidant capacity.

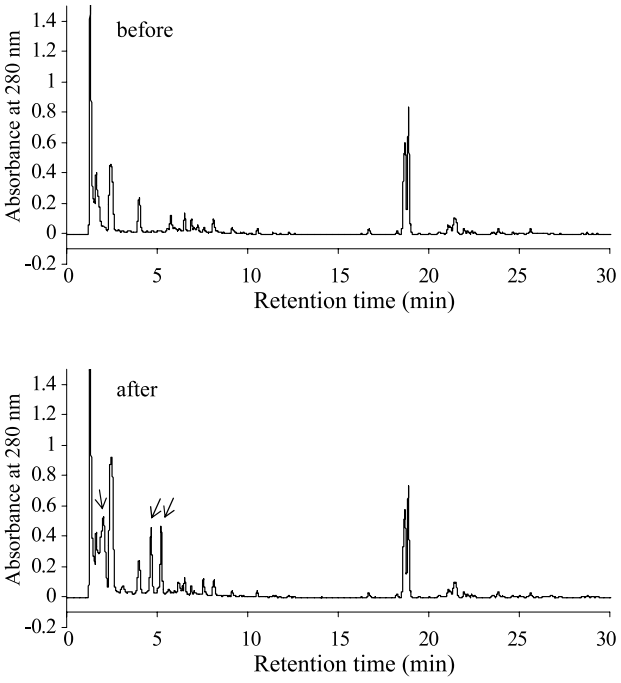

Fig. 2. Reverse-phase (C_{18}) HPLC of the crude methanolic extract from Tomkathi Saibua before and after the thermal process

Arrows indicate three major peaks found in the sample after sterilization.

Conclusions

This investigation showed that normally cooked foods containing indigenous vegetables as their main ingredients possess antioxidant capacity, phenolic content, and antimutagenicity. Applying greater heat by thermal sterilization does not cause deterioration in antioxidant and antimutagenicity. On the contrary, it enhances both properties. Thus, high-level heat treatment is a useful tool in improving the health benefits of some foods.

References

1. Bu-Abbas, A. et al. (1994) Marked antimutagenic potential of aqueous green tea extracts: mechanism of action. *Mutagenesis*, **9**, 325–331.
2. Ikken, Y. et al. (1999) Antimutagenic effect of fruit and vegetable ethanolic extracts against N-nitrosamines evaluated by the Ames test. *J. Agric. Food Chem.*, **47**, 3257–3264.
3. Jiratanan, T. & Liu. R.H. (2004) Antioxidant activity of processed table beets *(Beta vulgaris* var. conditiva*)* and green bean (*Phaseolus vulgaris* L.). *J. Agric. Food Chem.*, **52**, 2659–2670.
4. Luthria, D.L. & Mukhopadhyay, S. (2006) Influence of sample preparation on assay of phenolic acids from eggplant. *J. Agric. Food Chem.*, **54**, 41–47.
5. Manzocco, L., Anese, M. & Nicoli, M. C. (1998) Antioxidant properties of tea extracts as affected by processing. *Lebennsmittel–Wissenschaft und-Technologie*, **31**, 694–698.
6. Nakahara, K. & Trakoontivakorn, G. (1999) Antioxidative and autimutagenic properties of some local agricultural products in Thailand. In Highlight of Collaborative Research Activities between Thai Research organizations and JIRCAS. March 3, Bangkok, Thailand, pp. 141–143.
7. Nakahara, K. et al. (2002) Antimutagenicity of some edible Thai plants, and a bioactive carbazole alkaloid, mahanine, isolated from *Micromelum minutum*. *J. Agric. Food Chem.*, **50**, 4796–4802.
8. Nuutila, A.M. et al. (2003) Composition of antioxidant activities of onion and garlic extracts by inhibition of lipid peroxidation and radical-scavenging activity. *Food Chem.,* **81**, 485–493.
9. Ohnishi, M. et al. (1994) Inhibitory effects of chlorogenic acids on linoleic acid peroxidation and hemolysis. *Phytochemistry*, **36**, 579–583.
10. Prachasaisoradech, W. (1999) Native Vegetables in the North, the Northeast and the South of Thailand. Department of Agriculture, Ministry of Agriculture & Cooperatives. Bangkok, Thailand.
11. Singleton, V. L. & Rossi, J. A. (1965) Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *Am. J. Enol. and Vitic.*, **16**, 144–158.
12. Surh, Y.J. (2002) Anti-tumour promoting potential of selected spice ingredients with antioxidative and anti-inflam-

matory activities: short review. *Food and Chem. Toxicol.*, **40**, 1091–1097.
13. Tangkanakul, P. et al. (2006) Antioxidant activity of Northern and Northeastern Thai foods containing indigenous vegetables. *Kasetsart J. (Nat. Sci.)*, **40** (Suppl.), 47–58.
14. Trakoontivakorn, G. et al. (1999) Identification of antimutagenic substances (Ames Test) from *Boesenbergia pandurata* Schl. (fingerroot) and *Languas galanga* (galanga). *JIRCAS J.*, **7**, 105–116.
15. Turkmen, N., Sari, F. & Veliogu, Y. S. (2005) The effect of cooking methods on total phenolics and antioxidant activity of selected green vegetables. *Food Chem.*, **93**, 713–718.
16. Velioglu, V.S. et al. (1998) Antioxidative activity and total phenolics in selected fruits, vegetables and grain products. *J. Agric.Food Chem.*, **46**, 4113–4117.
17. Vinitketkumnuen, U., et al. (1994) Antimutagenicity of lemon grass (*Cymbopogon citratus* Stapf) to various known mutagens in salmonella mutation assay. *Mutat. Res.,* **341**, 71–75.
18. Vinson, J.A., Hao, Y. & Zubic, S.K. (1998) Food antioxidant quantity and quality in foods: vegetables. *J. Agric. Food Chem.*, **46**, 3630–3634.