

Dietary Intake of Spices and Herbs in Habitual Northeast Thai Diets

Tantipopipat S, Boonpraderm A, Charoenkiatkul S, Wasantwisut E & Winichagoon P

Institute of Nutrition, Mahidol University (INMU), Salaya, Nakhon Pathom, 73170 Thailand

ABSTRACT

Spices and herbs are rich in polyphenols and widely used in habitual diets in the tropical regions. To elucidate their effects on human health, intake of the portion of spices and herbs from habitual diets should be determined. Consumption patterns were determined from 24-hour records or recalls of 181 men and 370 women in Khonkaen and Ubon Ratchathani provinces, representing upper and lower northeast Thailand. There was a slight variation in dishes, but twelve spices/herbs were commonly used in the two areas. The amounts of spices/herbs in the four most common dishes (Somtum, Jaew, Pon and Kang-Nor-Mai) were estimated by weighing ingredients before and after cooking. The average amount of spices/herbs consumed was 4.9, 26.1, 14 and 11 g/meal, contributing 36.6, 43.1, 20.6 and 29.8 mg polyphenols/meal for Somtum, Jaew, Pon and Kang-Nor-Mai, respectively. Chili was common in all recipes, with an average amount of 8.3-27.5 mg polyphenols/meal. In conclusion, habitual northeast Thai diets contain several spices/herbs and a substantial amount of polyphenols was commonly consumed.

Keywords: Herbs, Northeast diets, polyphenols, portion size, spices, Thailand

INTRODUCTION

Spices and herbs have long been used as condiments in several cuisines across the tropical countries including Thailand (Eigner & Scholz, 1999; Lampe, 2003; The National Identity Office, Thailand, 2004). Plant leaves used in cooking are referred to as culinary herbs. Other parts of plants in dried form containing volatile oils or aromatic flavors, such as buds (cloves), bark (cinnamon), roots (ginger), berries (peppercorns), aromatic seeds (cumin), and the stigma of a flower (saffron), are classified as spices (Banchob, 2000a; Banchob, 2000b; Kritsanapun, 1994; Kritsanapun, 1995). The same plants can be classified as both herb

and spice, depending on the parts used. For example, coriander leaf is an herb, while its dried seed is a spice. Herbs and spices are rich in phenolic compounds. Polyphenols have been reported to be potent inhibitors of non-heme iron absorption which has been demonstrated both *in vitro* and *in vivo* (Brune, Rossander & Hallberg, 1989; Cook, Reddy & Hurrell, 1995; Gillooly *et al.*, 1984; Hurrell, Reddy & Cook, 1999; Lynch, 1997; Rozo, Valez & Garcia, 1985; Samman *et al.*, 2001; Tuntawiroon *et al.*, 1991). Various polyphenols also demonstrate anti-oxidant, anti-inflammatory, anti-carcinogenic and other biological activities, which may be important for chronic disease prevention. An important question is how much needs to be eaten to

have a beneficial effect. Intakes of 1, 0.5 and 4 g/person/day of spices/herbs were reported in Europe, New Zealand and USA, respectively (Fowles, Mitchell & McGrath, 2001). In the Indian subcontinent, turmeric consumption was estimated to be 1.5 - 2.5 g/person/day (Chainani-Wu, 2003; Eigner & Scholz, 1999; Sharma *et al.*, 2001), or as much as 4 g/day in one study (Thatte & Dahanukar, 1986). To elucidate the impact of spices and herbs on human health, it is essential to know the amounts consumed in habitual diets.

To our knowledge, data on the amount of spices/herbs consumed in typical diets are limited. We conducted a study in two rural northeast (NE) areas in Thailand. We first identified 10 most popular dishes which are commonly consumed in habitual diets. Subsequently, portions of the dish eaten by individuals were estimated, and amounts of individual spices/herbs contained in these dishes determined. Finally, the polyphenol contents (as gallic acid equivalents) in these most popular dishes were analysed, and the total amount of polyphenols per serving per day were calculated.

METHODOLOGY

Study areas and population

Dietary intake data were collected in two purposively selected areas, Khon-kaen and Ubon Ratchathani provinces, in NE Thailand. The two provinces represent upper and lower NE Thailand, respectively. Khon-kaen is the commerce and political centre of the northeast. Due to its geographical location, it emerged as the trade centre with the Indo-china sub-region, and Khon-kaen is one of the fastest growing provinces economically. Ubon Ratchathani, on the other hand, is a more culturally and historically traditional community. It shares with Laos PDR the Mekhong River on the east and Cambodia in the south.

In Khon-kaen province, the dietary data were taken from a population-based study

on dietary calcium intake of rural dwellers (Pongchaiyakul *et al.*, 2005). Briefly, the dietary intakes of apparently healthy adults aged 20-85 yrs old (181 males and 250 females) residing in the rural area of the provincial district were obtained from a three-day food record. One weekday 24-hour recall data of each study participant was used in the present study. In Ubon Ratchathani province, a cross-sectional study was conducted in Trakarn Phutphon district, where a high prevalence of anemia in infants and school-aged children was reported (Maw, 2001; Thurlow *et al.*, 2005). One hundred and twenty women were interviewed using one weekday 24-hour dietary recall. These women resided in 10 poor rural sub-districts which are largely rice growing areas. Description of the area has been reported elsewhere (Thurlow *et al.*, 2005). The general characteristics of the typical diets are plant-based, low fat, and have rice as the major energy source.

Identifying popular dishes and estimating the consumption of spices and herbs

For each meal consumed, name(s) of the dish(s), and portion size of spices/herbs in individual dishes and cooking methods (stir-fried, boiled/steamed, deep-fried, pan-fried, roasted/grilled), were elicited using a 24-hour recall method. All interviews were conducted by trained interviewers. Food models of freshly prepared foods, weighing scales, common household utensils and standard measuring cups and spoons were used to aid the portion-size estimation. From these data, dishes consumed in both provinces were ranked, and the 10 most commonly eaten dishes were consolidated. Spices/herbs which were common ingredients in these dishes were ranked according to the frequency of recalls. The description and ingredient composition of the local dishes are presented as in the annex (Thasanasuwan & Kijboonchoo, 1993).

Determination of portion eaten of spices/herbs

The top four most popular dishes (Somtum, Jaew, Pon and Kang-Nor-Mai) containing relevant spices/herbs in their recipes and common between the two study areas were chosen for actual cooking by ten housewives in Trakarn Phutphon area. This was done to obtain a range of recipes. Each woman was assigned to prepare raw materials and cook each of the four dishes for serving 4-5 persons. Before cooking, each ingredient, especially spices or herbs, was weighed using a digital balance which has a maximum capacity of 2 kg (SOEHNLE, Switzerland) with a precision of ± 1 g. After cooking of the individual dishes, total weight of each dish was determined, and amount of cooked spices and herbs were derived from its weight composition in the raw stage of the respective dishes. Three women living in the neighborhood of each house were then asked to aliquot an individual portion eaten of each dish. The portion of spices/herbs eaten per meal was accordingly calculated.

Determination of polyphenol content of relevant spices and herbs

The identified fresh spices/herbs from the top four most popular dishes were purchased from three main local markets in the Muang district of Ubon Ratchathani and pooled as a composite sample to determine polyphenol content. Total phenolic contents in freeze-dried spices/herbs were extracted with 50% dimethylformamide in acetate buffer for 16 hours. The extracted polyphenol content was then quantified by spectrophotometry after reacting with Folin-Ciocalteu reagent (Singleton & Rossi, 1965). The polyphenol content of individual samples was analysed in triplicates, and is reported as gallic acid equivalents.

Statistical analysis

Descriptive statistics were analysed using SPSS version 13.

RESULTS

Dish and cooking patterns

The basic staple dish of both study sites consisted of steamed glutinous rice served with one or two or occasionally three spicy dishes per meal. Food is usually prepared in the morning and consumed at breakfast, lunch and sometimes dinner. Local recipes consisted of several culinary spices/herbs as condiments or seasoning vegetables. A wide variety of either fresh or blanched vegetables are usually prepared as side dishes. Dish varieties showed a similar pattern in both study areas, although the ranking position based on the frequency of consumption was slightly different (Table 1).

Common dishes and spices/herbs used

Eight dishes (Jaew, Somtum, deep-fried meat, Kang, grilled meat, Pon, Toam and Laab) were common in the two study areas. However, only six of these eight dishes (Jaew, Somtum, Kang, Pon, Toam and Laab) contained spices/herbs (Thasanasuwan & Kijboonchoo 1993). The common spices/herbs consumed were consolidated and twelve items were identified. They are garlic, chili pepper, tamarind, lemon grass, shallot, galangal, kaffer lime leaves, shallot, hairy basil leaves, mints, Bai-ya-nang (a local vegetable herb), and fennel leaves.

The portion eaten per meal of each relevant spice/herb from the four most commonly eaten dishes (Somtum, Jaew, Pon and Kang-Nor-Mai) was determined. Tables 2-5 show the average portion eaten of spices/herbs in these four dishes. Only the spices/herbs which were frequently eaten (i.e., at least 5 households used in their recipes) were selected to determine polyphenol contents. These are Bai-ya-nang, chili, galangal tube, garlic, Pak-kyheng, tamarind and shallot. Table 6 presents the contents of polyphenols expressed as gallic acid equivalents in these spices/herbs. The average polyphenol contents ranged from 81 to 1406 mg/100 g fresh weight.

Table 1. Frequency (percent) and ranking of common dishes in habitual diets in rural NE Thailand

Dish names	Thai name	Khonkaen		Ubon	
		Freq (%)	rank	Freq (%)	rank
Mashed chili mixed					
with condiment	Jaew	275 (15.9)	1	55 (10.4)	4
Papaya salad	Somtum	221 (12.8)	2	84 (15.9)	1
Deep - fried meat	-	212 (12.3)	3	61 (11.6)	3
Vegetable soup with/ without meat	Kang	139 (8)	4	42 (8)	6
Grilled meat	-	139 (8)	5	62 (11.7)	2
Minced meat with chili and condiment	Pon	134 (7.8)	6	50 (9.5)	5
Meat soup	Toam	107 (6.2)	7	34 (6.6)	7
Boiled meat with little water	Om	82 (4.8)	8	10 (1.9)	13
Minced meat salad	Laab	81 (4.7)	9	22 (4.2)	9
Boiled meat and condiments	Soup	71 (4.1)	10	4 (0.8)	17
Small fish steamed with chili paste	Moak	63 (3.6)	11	-	-
Steamed meat with herbs	-	42 (2.4)	12	20 (3.8)	10
One plate dish	-	36 (2.1)	13	25 (4.7)	8
Stir-fried vegetables	-	21 (1.2)	14	13 (2.5)	12
Sour meat salad	Yum	20 (1.1)	15	4 (0.8)	17
Stir-fried meat with spices	Pud phed	20 (1.1)	16	7 (1.3)	14
Sour raw meat salad	Koi	19 (1.1)	17	5 (0.9)	15
Fish paste curry	Namya	18 (1.0)	18	5 (0.9)	15
Sour fermented fish	Som-pla	13 (0.7)	19	-	-
Roasted meat	Kua	10 (0.6)	20	-	-
Curry soup with coconut	Kang kati	1 (0.06)	21	-	-

Table 2. Portion eaten per meal of polyphenols containing spices and herbs in papaya salad (Somtum)

Frequency of eating	Spices/herbs	Mean \pm SD (g)	Median (g)	Range (g)
30	Garlic	2.0 \pm 1.6	1.6	0.2-7.0
18	Chili pepper, dried	1.0 \pm 0.4	0.9	0.5-1.8
15	Tamarind	1.9 \pm 1.9	1.3	0.4-8.0
12	Chili pepper, fresh	4.2 \pm 1.4	4.1	1.9-6.6
12	Lime, juice	2.1 \pm 2.6	0.8	0.3-6.9

Portion size and polyphenol contents in four most common dishes

Table 7 shows the portion eaten and total polyphenol contents of spices/herbs used in commonly consumed dishes. Each recipe contained at least 3 spices/herbs. Either

fresh or dry chili was commonly used across the four dishes and the average polyphenol content of chili ranged from 8.3 mg/meal for Somtum to 27.5 mg/meal for Jaew. Garlic bulb was used in all four dishes, but at a lower frequency in Kang-Nor-Mai (Table 5).

Table 3. Portion eaten per meal of polyphenols containing spices and herbs in local chili sauce (Jaew)

<i>Frequency of eating</i>	<i>Spices/herbs</i>	<i>Mean ± SD (g)</i>	<i>Median (g)</i>	<i>Range(g)</i>
30	Shallot bulbs	10.5 ± 4.5*	8.9	4.5-24.2
27	Garlic	2.5 ± 1.1	2.5	1.0- 5.6
15	Galangal, tube	2.9 ± 1.7	2.4	1.5- 7.5
15	Chili pepper, fresh	10.2 ± 5.3	11.5	2.8-17.2
9	Chili pepper, ground	1.2 ± 0.4	1.1	0.7- 1.7
6	Kaffer lime, leaves	0.2 ± 0.1	0.2	0.1- 0.3
6	Lemon grass	1.5 ± 0.4	1.5	0.7- 1.9
6	Dried chili pepper	2.2 ± 0.6	2.4	1.1- 2.8
3	Tamarind, ripe	2.3 ± 1.0	2.5	1.2- 3.2

Table 4. Portion eaten per meal of polyphenols containing spices and herbs in seasoned minced meat (Pon)

<i>Frequency of eating</i>	<i>Spices/herbs</i>	<i>Mean ± SD (g)</i>	<i>Median (g)</i>	<i>Range (g)</i>
24	Shallot bulb	8.4 ± 5.6	6.8	1.1-20.8
21	Garlic	1.8 ± 0.6	1.7	0.6- 3.1
21	Chili pepper	3.8 ± 1.3	3.5	1.8- 7.1
9	Chili pepper, ground	0.8 ± 0.3	0.7	0.3- 1.3
9	Coriander	0.9 ± 0.8	0.8	0.1- 2.1
6	Fermented fish	7.2 ± 1.2	7.4	5.3- 8.3
3	Climbing perch	7.0 ± 2.4	8.2	4.2- 8.6
3	Galangal, tube	2.8 ± 0.9	2.6	2.1- 3.8
3	Mint	0.6 ± 0.2	0.6	0.4- 0.8
3	Pak-kyheng (local vegetable)	0.1 ± 0.0	0.1	0.1- 0.1

The mean polyphenol content of garlic was less than 2.0 mg/person/meal. Shallot bulb was common in three dishes but was less frequently used in Kang-Nor-Mai (Table 5). The average polyphenol content per meal of shallot bulb was 8.8 and 11 mg for Pon and Jaew, respectively. Two indigenous herbs, Bai-ya-nang and Pak-kyheng were used only in Kang-Nor-Mai. The mean polyphenol content per meal of Bai-ya-nang was only 1.8 mg/meal but that of Pak-kyheng was 10 times higher (18.6 mg/meal). Only Jaew contained galangal tube and the average polyphenol content was 2.6 mg/meal.

Tamarind was only used in Somtum recipe, but the mean polyphenol content per meal was high (26.7 mg), comparable to that from chili used in Jaew (27.5 mg). The average polyphenols per dish was 36.6, 43.1, 20.6 and 29.8 mg/dish in Somtum, Jaew, Pon and Kang-Nor-Mai, respectively.

DISCUSSION

To our knowledge this is the first study to estimate intake of culinary spices and herbs used in habitual diets of northeast Thailand. However, several indigenous spices/herbs

Table 5. Portion eaten per meal of polyphenols containing spices and herbs in spicy bamboo shoot soup (Kang-nor-Mai)

Frequency of eating	Name	Mean \pm SD (g)	Median (g)	Range (g)
30	Bai-ya-nang	0.7 \pm 0.4	0.7	0.2- 2.4
27	Chili pepper	3.5 \pm 1.8	3.0	1.0- 7.5
24	Pak-kyheng	6.8 \pm 4.6	6.1	1.8-23.8
12	Cha-om	4.3 \pm 2.3	3.6	1.5- 8.6
6	Pumpkin, young leaves	17.1 \pm 6.8	15.7	11.2-29.9
6	Egg plant	10.9 \pm 7.9	7.8	3.2-21.7
3	Chili pepper, dried	0.7 \pm 0.2	0.7	0.5- 0.8
3	Pak-knam	26.4 \pm 4.5	26.2	22.0-30.9
3	Pak-e-lum	4.8 \pm 2.3	4.3	2.7- 7.3
3	Swamp morning glory, red stem	18.5 \pm 9.0	22.7	8.1-24.7
3	Egg plant, big	10.1 \pm 5.0	12.4	4.5-13.5
3	Garlic	0.5 \pm 0.2	0.6	0.2- 0.6
3	Shallot bulb	2.7 \pm 1.3	3.4	1.2- 3.6
3	Sponge gourd	19.5 \pm 9.3	15.0	13.3-30.2
3	Hairy basil	2.5 \pm 1.1	2.4	1.5- 3.7

Table 6. Polyphenols as gallic acid equivalents of commonly used spices/herbs in typical diets of NE rural Thai households (n=3 for each item)

Plant species (common/local name)	Part of plant	Processing	Polyphenols (mg/100 g)	
			fresh weight	dry weight
<i>Capsicum frutescens</i> (Chili pepper)	Fruit	Fresh	270 \pm 1.2	1,369 \pm 5.9
<i>Capsicum frutescens</i> (Chili pepper)	Fruit	Dry	834 \pm 12.2	932 \pm 13.6
<i>Allium sativum</i> (Garlic)	Bulb	Fresh	81 \pm 1.2	225 \pm 2.8
<i>Allium ascalonicum</i> (Shollot)	Bulb	Fresh	105 \pm 5.7	674 \pm 37
<i>Tamarindus indica</i> (Tamarind)	Pod	Fresh	1,406 \pm 62	2,175 \pm 79
<i>Alpinia galanga</i> (Galangal)	Tube	Fresh	91 \pm 2.2	1609 \pm 38
<i>Tiliacora triandra</i> (Bai-ya-nang)	Leaves	Cooked	262 \pm 9.2	979 \pm 28.2
<i>Limnophila aromatica</i> (Pak kyheng)	Leaves	Cooked	274 \pm 24.1	4,668 \pm 335

are also commonly used in local recipes of other parts of the country (Sorajjapun, 2001).

The northeast typical diets contained at least 11 spices/herbs (chili pepper, lemon grass, garlic, shallot, tamarind, galangal tube, hairy basil leaves, Bai-ya-nang (Thai vegetable herb), kaffer lime leaves, fennel leaves, mint). The portion eaten per meal of each kind of spices/herbs varied according to recipes and individual preference. From

weighed food records of the four most popular dishes, each recipe contained at least three polyphenol rich spices/herbs (Tables 2-5). The uses of multiple spices/herbs in NE Thai diets are similar to those studies reported from Nepal and Indonesia. In Nepal, at least 8 spices/herbs were used in each of the common habitual diets (Eigner & Scholz, 1999). The most frequently eaten lentils (*dal*) served with rice in rural Nepal

Table 7. Portion eaten (mean \pm SD, g) of spices and herbs and average amounts of polyphenols (mg/meal) (in parenthesis)

Spice/herb	Somtum	Jaew	Pon	Kang-Nor-Mai
Bai-ya-nang	-	-	-	0.7 \pm 0.4 (1.8) ¹
Chili, dried	1.0 \pm 0.4 (8.3) ⁵	-	-	-
Chili, fresh	-	10.2 \pm 5.3 (27.5) ⁶	3.8 \pm 1.3 (10.3) ⁴	3.5 \pm 1.8 (9.4) ²
Galangal	-	2.9 \pm 1.7 (2.6) ⁶	-	-
Garlic	2.0 \pm 1.6 (1.6) ¹	2.5 \pm 1.1 (2.0) ²	1.8 \pm 0.6 (1.5) ⁴	-
Pak-kyheng	-	-	-	6.8 \pm 4.6 (18.6) ³
Tamarind	1.9 \pm 1.9 (26.7) ⁶	-	-	-
Shallot bulb	-	10.5 \pm 4.5 (11.0) ¹	8.4 \pm 5.6 (8.8) ¹	-
Average amount of spice& herb/dish (g)	4.9	26.1	14.0	11.0
Average polyphenol/ dish (mg)	36.6	43.1	20.6	29.8

¹⁻⁶ number of observations: ¹n =30, ²n = 27, ³n = 24, ⁴n = 21, ⁵n = 18, ⁶n = 15

contained turmeric, asa-foetida, black pepper, black cumin seeds, fresh ginger, onion, coriander leaves and green chili. Using focus group discussion, several spices/herbs e.g., chili, turmeric, ginger, onions, garlic, lemon grass and galangal, were found to be used as condiments in the typical food culture of Muslim Minangkabau in West Sumatra (Lipoeto, *et al.*, 2001). Chili was usually used in dishes that contain coconut milk. In the present study, either fresh or dried chili was used in all popular dishes (Table 7). The average intake of spices/herbs from Somtum was 4.9 g spices/herbs per dish. This amounts to 14.7 g/person/day if it is consumed in all three meals (which is quite common). This estimated intake/person/day is comparable to that consumed in the usual diets of Indians, and much higher than those consumed in Europe, New Zealand and USA (0.5, 1.0 and 4.0 g/person per day, respectively) (Fowles, *et al.*, 2001). The reported intake among adult Indians was as high as 4 g of turmeric daily (Thatte & Dahanukar, 1986) and 50 g of garlic per week (Sainani *et al.*, 1979; Lipoeto *et al.*, 2001).

Polyphenols contained in several common spices are potent iron absorption

inhibitors (Brune, *et al.*, 1989; Cook *et al.*, 1995; Gillooly *et al.*, 1983; Hurrell *et al.*, 1999; Lynch, 1997; Roza, Valez & Garcia, 1985; Samman *et al.*, 2001; Tuntawiroon *et al.*, 1991; Tuntipopipat *et al.*, 2006). Iron absorption is strongly inhibited by phenolic compounds in iron fortified bread meal in a dose response manner at 20-50 mg polyphenols/meal as tannic acid equivalents (Brune, Hallberg & Skanberg, 1991). Non-heme iron absorption was further inhibited by pure tannic acid or phenolic compounds in foods or beverages, such as, tea, coffee, oregano, and spinach, consumed with the iron fortified bread meal. The polyphenol content in the average portion of meals eaten found in this study is about 20-40 mg/meal (Table 7). The inhibitory effects of chili pepper, garlic, 'Pak-kyheng', shallot and turmeric and green curry paste, which contain a mixture of some of these spices, have been shown to reduce iron dialysability in a dose dependent manner from 20-90% (Tuntipopipat *et al.*, 2009). Further, consumption of chili pepper containing 25 mg polyphenols as gallic acid equivalents reduced iron absorption in a basic rice and vegetable meal by 38% (Tuntipopipat *et al.*, 2006). A high consumption of these spices

and herbs in diets which contained a small amount of or no meat could contribute importantly to lower bioavailability of dietary iron.

On the other hand, polyphenols have been reported to have beneficial effect in lowering risks of cardiovascular diseases (Tapsell *et al.*, 2006). Health benefits of herbs/spices consumption, either from their extracts or food sources, have been shown both in the *in vitro* and *in vivo* studies (Tapsell *et al.*, 2006). Garlic and lemon grass consumption are associated with a reduction in cardiovascular risk factor including total cholesterol, LDL-cholesterol and triglyceride levels. Several spices/herbs including turmeric, garlic, red chili, fenugreek, ginger, basil, anise, fennel, cloves, coriander, galangal and cardamom, have demonstrated anti-cancer effects *in vitro* and in animal models (Aggarwal & Shishodia, 2006). However, most of the studies used organic or aqueous extracts of spices or herbs to demonstrate their effects. It is imperative that the amount of combined spices and herbs consumed in typical diets be evaluated on its beneficial effects, especially in a well-controlled clinical trial.

CONCLUSIONS

Our study showed that several spices/herbs are widely consumed in local NE Thai diets. Each popular local recipe contains at least 3 spices/herbs. The total spices/herbs intake was more than 14.7 g/day. The estimated polyphenol intake derived from spices/herbs was more than 20 mg/meal. High consumption of polyphenol rich spices and herbs in the habitual diets may be an important factor interfering with dietary iron making it less bioavailable for absorption. On the other hand, whether this level of intake of polyphenols contributes to preventing the emerging problems of diet-related chronic diseases needs to be evaluated.

REFERENCES

- Aggarwal BB & Shishodia S (2006). Molecular targets of dietary agents for prevention and therapy of cancer. *Biochem Pharm* 71: 1397-1421.
- Banchob M (2000a). Indigenous Northeast Thailand Herbs Book No.1-2: Institute of Herbal Research, National Institute of Health, Thanacharoensin Printing (Thai).
- Banchob M (2000b). Indigenous Northeast Thailand Herbs Book Bo.3: Institute of Herbal Research, National Institute of Health of Thailand, AR Printing Mass Product Ltd (Thai).
- Brune M, Hallberg L & Skanberg AB (1991). Determination of iron-binding phenolic groups in foods. *J Food Sci* 56: 131-137.
- Brune M, Rossander RL & Hallberg L (1989). Iron absorption and phenolic compounds: importance of different phenolic structures. *Eur J Clin Nutr* 43: 547-557.
- Chainani-Wu N (2003). Safety and anti-inflammatory activity of curcumin: A component of tumeric (*Curcuma longa*). *J Altern Complem Med* 9: 161-168.
- Cook JD, Reddy MB & Hurrell RF (1995). The effect of red and white wines on non heme-iron absorption in humans. *Am J Clin Nutr* 61: 800-804.
- Eigner D & Scholz D (1999). *Ferula asa-foetida* and *Curcuma longa* in traditional medical treatment and diet in Nepal. *J Ethnopharm* 67: 1-6.
- Fowles J, Mitchell J & McGrath H (2001). Assessment of cancer risk from ethylene oxide residues in spices imported into New Zealand. *Food Chem Toxicol* 39: 1055-1062.

- Gillooly M, Bothwell TH, Charlton RW, Torrance JD, Bezwoda WR, MacPhail AP, Derman DP, Novelli L, Morrall P & Mayet F (1984). Factors affecting the absorption of iron from cereals. *Br J Nutr* 51: 37-46.
- Gillooly M, Bothwell TH, Torrance JD, MacPhail AP, Derman DP, Bezwoda WR, Mills W, Charlton RW & Mayet F (1983). The effects of organic acids, phytates and polyphenols on the absorption of iron from vegetables. *Br J Nutr* 49: 331-342.
- Hurrell RF, Reddy M & Cook JD (1999). Inhibition of non-haem iron absorption in man by polyphenolic containing beverage. *Br J Nutr* 81: 289-295.
- Kritsanapun W (1994). Herbs: Chulalongkorn University Book Center (Thai).
- Kritsanapun W (1995). The Usefulness of Herbs: Faculty of Pharmacy; Mahidol University (Thai).
- Lampe JW (2003). Spicing up a vegetarian diet: chemopreventive effects of phytochemicals. *Am J Clin Nutr* 78: 579S-583S.
- Lipoeto NI, Agus Z, Oenzil F, Masrul M, Wattanapenpaiboon N & Wahlqvist ML (2001). Contemporary Minangkabau food culture in West Sumatra, Indonesia. *Asia Pac J Clin Nutr* 10: 10-16.
- Lynch SR (1997). Interaction of iron with other nutrients. *Nutr Rev* 55: 102-110.
- Maw N (2001). Effect of daily versus intermittent iron supplementation on iron status of Thai infants. Food and nutrition for development, M Sc thesis. Nakhon Pathom, Thailand, Mahidol University.
- Pongchaiyakul C, Nguyen V, Kosulwat V, Rojroongwasinkul N, Charoenkiatkul S & Rajatanavin R (2004). Effects of physical activity and dietary calcium intake on bone mineral density and osteoporosis risk in a rural Thai population. *Osteoporosis Inter* 15: 807-813.
- Pongchaiyakul C, Nguyen V, Kosulwat V, Rojroongwasinkul N, Charoenkiatkul S & Rajatanavin R (2005). Effect of urbanization on bone mineral density: a Thai epidemiological study. *BMC Musculo-skeletal Disord* 6: 5-11.
- Rozo MP, Valez J & Garcia LA (1985). Effect of polyphenols of coffee pulp on iron absorption. *Arch Latinoam Nutr* 35: 287-296.
- Sainani GS, Desai DB, Gorhe NH, Natu SM, Pise DV & Sainani PG (1979). Effect of dietary garlic and onion on serum lipid profile in Jain community. *Indian J Med Res* 69: 776-780.
- Samman S, Sandstrom B, Toft MB, Bukhave K, Jensen M, Sorensen SS & Hansen M (2001). Green tea or rosemary extract added to foods reduces non-heme iron absorption. *Am J Clin Nutr* 73: 607-612.
- Sharma R, McLelland H, Hill K, Ireson C, Euden S, Manson M, Pirmohamed M, Marnett L, Gescher A & Steward W (2001). Pharmacodynamic and pharmacokinetic study of oral curcuma extract in patients with colorectal cancer. *Clin Cancer Res* 7: 1894-1900.
- Singleton V & Rossi JAJ (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *Am J Enol Vitic* 16: 144-158.

- Sorajjapun A (2001). Local Southern Thai Food: Songkla Rajabhat University (Thai).
- Tapsell LC, Cobiac L, Sullivan DR, Fenech M, Patch CS, Roodenrys S, Keogh JB, Clifton PM, Williams PG, Fazio VA & Inge KE (2006). Health benefits of herbs and spices: the past, the present, the future. *Med J Aust* 185: S1-S24.
- Thasanasuwan W & Kijboonchoo K (1993). Composition and nutrients content of typical Isaan food. Nakhon Pathom, Thailand, Institute of Nutrition, Mahidol University (Thai).
- Thatte UM & Dahanukar SA (1986). Ayurveda and contemporary scientific thought. *Trends Pharm Sci* 7: 247-251.
- The National Identity Office (2004). Thai Herbs and Herbal Products. Srimuang Printing Co., Ltd. Bangkok, Thailand:
- Thurlow RA, Winichagoon P, Green T, Wasantwisut E, Pongcharoen T, Bailey KB & Gibson RS (2005). Only a small proportion of anemia in northeast Thai schoolchildren is associated with iron deficiency. *Am J Clin Nutr* 82: 380-387.
- Tuntawiroon M, Sritongkul N, Brune M, Rossander-Hulten L, Pleehachinda R, Suwanik R & Hallberg L (1991). Dose-dependent inhibitory effect of phenolic compounds in foods on nonheme-iron absorption in men. *Am J Clin Nutr* 53: 554-557.
- Tuntipopipat S, Judprasong K, Zeder C, Wasantwisut E, Winichagoon P, Charoenkiatkul S, Hurrell R & Walczyk T (2006). Chili, but not turmeric, inhibits iron absorption in young women from an iron-fortified composite meal. *J Nutr* 136: 2970-2974.
- Tuntipopipat S, Charoenkiatkul S, Zeder C & Siriprapa P (2009). Inhibitory effects of spices and herbs on iron availability. *Int J Food Sci Nutr* 60: Suppl 1:43-55.

Appendix

Typical NE Thai dishes contain several spices, herbs and vegetables indigenous and grown in the local areas. The main cooking methods are boiling, roasting/grilling, and raw meat with added lime. Oil is not typically used. Raw fermented fish sauce, salt and lemon juice may be the most commonly used condiments, although fish sauce may be now more readily available from the market. The following is a description of the typical dishes reported in the study.

- 1. Somtum (vegetable salad)**
Somtum is a spicy vegetable salad. The main ingredients are shredded vegetables, such as green papaya, cucumber and string bean. Fresh or dry chili pepper and garlic are pounded and the shredded vegetables added, seasoned with fish sauce; fermented fish sauce (Nam pra la) is traditionally used uncooked with small pieces of fish meat) and lemon juice.
- 2. Jaew**
Jaew is a sauce composed of chopped garlic, shallot bulb, dry or fresh chili pepper, seasoned with fish sauce or fermented fish sauce and lime juice, and less frequently, mint or tamarind or minced meat may be added.
- 3. Pon**
Whole fish or frog is boiled and the broth is saved. The cooked meat is minced and mixed with a blend of roasted garlic, chili pepper, shallot bulb, then added back to a small amount of broth.
- 4. Soup**
Similar to Pon, fish or frog are main ingredients, but they are grilled instead of boiled. The meat is minced and mixed with a small amount of water. Roasted garlic, chili pepper, and shallot bulb are commonly used. Mint, dill or spring onions are often added.
- 5. Kang**
The main ingredient is meat or vegetables boiled with galangal, lemon grass and hairy basil leaves. Salt, fish sauce or fermented fish sauce is added to the taste. Some recipes may be seasoned with shallot bulbs, chili pepper or other indigenous herbs (e.g., Bai-ya-nang, Pak-ka-yheng or Pak-Tiew).
- 6. Ooh**
The main ingredients and cooking method are the same as Kang but the content is simmered until the volume is reduced by about one-fifth.
- 7. Moak**
The main ingredients may be fish, frog, mushroom or minced chicken mixed with condiments similar to Ooh. The mixed ingredients are wrapped in banana leaves then, steamed or grilled.
- 8. Toam**
The main ingredients are fish, chicken, beef or internal organs, cooked in water, seasoned with salt or fish sauce, galangal, lemon grass and tamarind leaves, until boiled. A variety of herbs e.g., shallot bulb, dill, chili pepper or tamarind, may be added.
- 9. Om**
The main ingredients and condiments are similar to Toam but seasoned with a greater variety of spices/herbs than Toam. Ground roasted rice is usually added for flavour, making the soup thicker than Toam.
- 10. Kua**
The main ingredients and condiments are similar to Om, except for roasted rice. A small amount of water or oil is used in the cooking. All ingredients are heated and stirred in a pan until almost dried (only 10-20% water is left)

11. Laab

Various meats, such as, raw fish, beef, chicken or pork can be used. Meat is minced and mixed with dried chili powder fish sauce or fermented fish sauce, and lemon juice. The ingredients are boiled with a small amount of water until the meat is medium-cooked. Mint, spring onion and roasted rice powder are usually added and mixed well before serving.

12. Koi

Thin slices of grilled beef or pork are mixed with the same condiments as Laab, but sliced lemon grass is also added.

13. Yum

Well-cooked meat is mixed with the same condiments as Laab, except for roasted rice. The taste is more sour than Laab.

14. Pudpheed

Fish or frog is stir-fried with curry paste and a variety of vegetables.

Source: Thassanasuwan and Kijboonchoo, 1993.