CHAPTER IV

DETERMINATION OF ARSENIC IN VEGETABLES

Before arsenic in vegetables can be determined by differential pulse polarographic technique, the vegetable sample must be subjected to the proper pretreatment procedures. First, the vegetable sample must be digested or ashed to destroy organic matter with as little loss of arsenic as possible since many arsenic compounds are quite volatile. Second, the seriously interfering ions such as Pb (II) ion must be removed quantitatively. The procedure for DPP analysis of arsenic in the vegetable sample as arsenite ion was previously described in chapter II. In order to compensate for matrix differences, the quantitative evaluation of arsenic in vegetables was preferably carried out by standard addition method.

4.1 Evaluation of methods of decomposing organic matter

In general, there are two means for destruction of organic matter in the sample to be analyzed. One is dry ashing by which the sample is ashed in a muffle furnace with or without ashing aid. Alternatively, sample may be wet-digested by means of chemicals such as HNO_3, H_2SO_4, $HClO_4$ and H_2O_2. These reagents may be used together or separately as required.

In this study, both dry ashing and wet digestion methods were comparatively performed. In dry ashing technique , no ashing aid was added to the vegetable sample to avoid extraneous impurity which could be introduced. In wet digestion, only 8.0 M HNO_3 was used for the same reason. The procedures were described in 2.3.5 for decomposition and dissolution, and in 2.3.6 for DPP analysis.

To assess the procedures, recovery results were carried out by treating arsenite standard solution in the same manner as the vegetable sample was analyzed. The data obtained are shown in Table 9 for dry ashing and in Table 10 for wet digestion as corrected for the reagent blanks. The percentage of arsenic recovery by dry ashing method was found to be higher (88.77%) than that by wet digestion method (71.61%).

4.2 Elimination of interferences

Two sets of DPP analyses of arsenic in the vegetable with and without the treatment of the cation exchange resins, Amberlite IR-120 (H), were studied. The procedure for this study was as presented in 2.3.5. The vegetable sample analyzed was Chinese kale. Figure 11 is DPP analysis of arsenic in Chinese kale decomposed by dry ashing process and followed with and without the cation exchange resin treatment. Figure 12 is DPP analysis of the sample vegetable

Table 9 Recovery data for As (III) as arsenite ion by dry ashing

Amount (μg As/cm^3)	i_p (μa) Before ashing	i_p (μa) After ashing	% Recovery
1.20	1.05	0.96	91.43
1.20	1.10	0.96	87.27
1.20	1.10	0.98	89.09
1.20	1.10	0.96	87.27
		Average	88.77

Table 10 Recovery data for As (III) as arsenite ion by wet digestion

Amount (μg As/cm^3)	i_p (μa) Before digestion	i_p (μa) After digestion	% Recovery
1.00	0.99	0.71	71.72
1.00	1.00	0.70	70.00
1.00	0.99	0.72	72.73
1.00	1.00	0.72	72.00
		Average	71.61

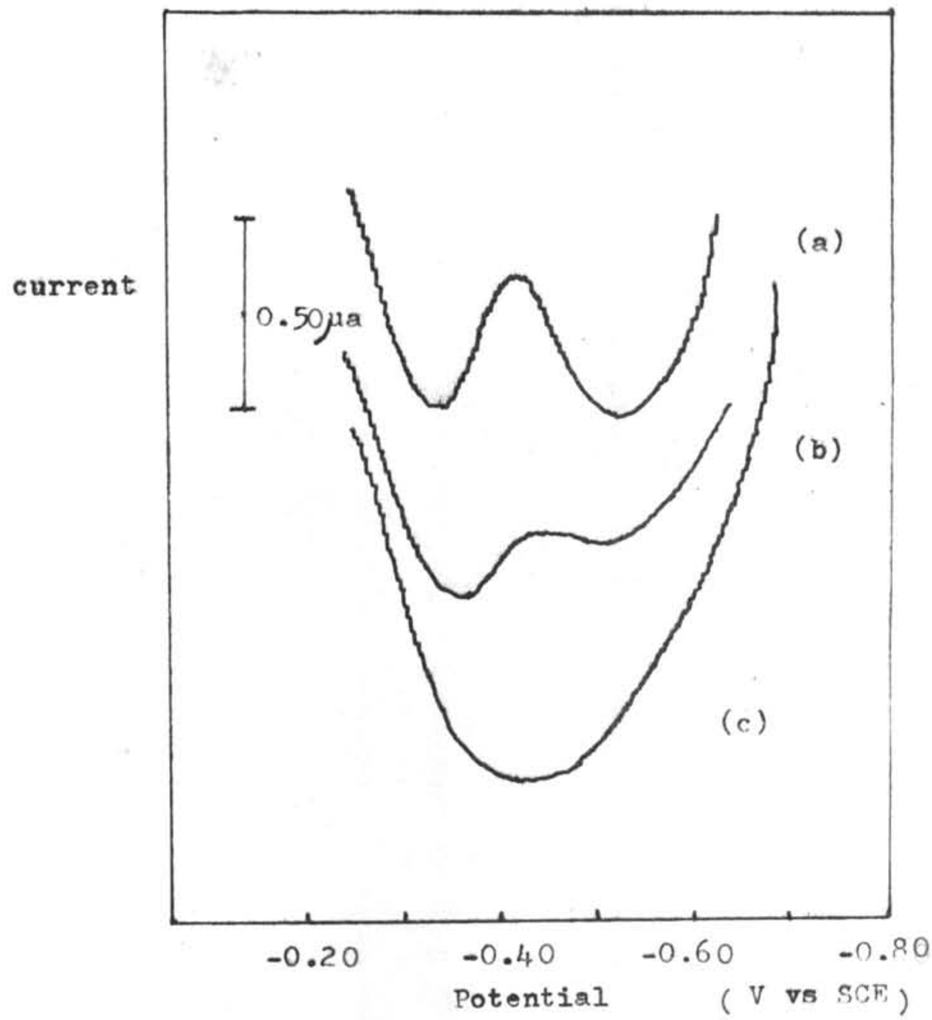

Figure 11 DPP of Chinese kale solution obtained from dry ashing process (a) without the cation exchange resin treatment, (b) with the resin treatment, and (c) DPP of blank solution.

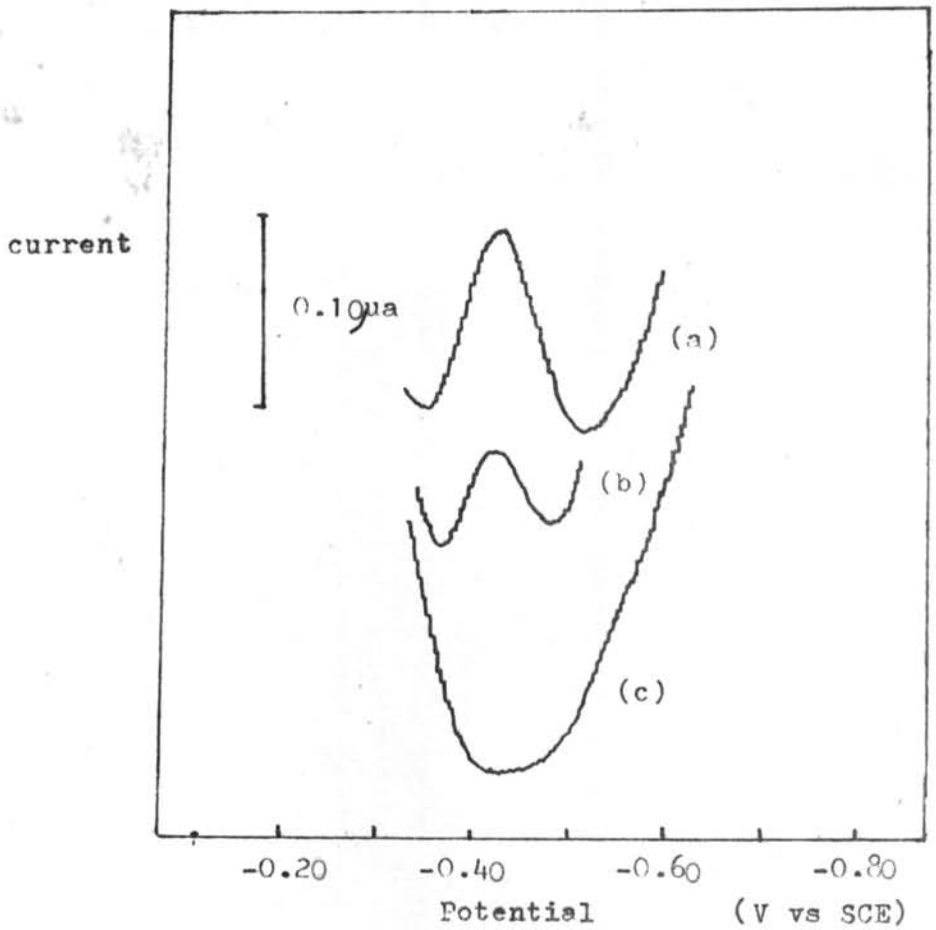

Figure 12 DPP of Chinese kale solution obtained from wet digestion process

(a) without the cation exchange resin treatment,

(b) with the cation exchange resin treatment,

and (c) DPP of blank solution.

species by wet digestion process. Data of this study are shown in Table 11. It can be seen that the higher peak currents of both dry ashing and wet digestion were obtained in the set of samples without treatment of the cation exchange resins. Differences in peak currents between samples with the cation exchanger treatment and samples without the cation exchanger treatment were due to interfering cations which were reduced at nearly the same potential as arsenite ion.

Table 11 DPP data for arsenic analyses in Chinese kale by dry ashing and wet digestion with and without the treatment of Amberlite IR-120 (H).

Method of organic matter decomposition	i_p^* (μa)	
	Without the resin	With the resin
Dry ashing	0.36 ± 0.01	0.11 ± 0
Wet digestion	0.09 ± 0	0.04 ± 0

* average peak current ± average deviation of 3 trials

4.3 Determination of arsenic in vegetables

Forty three vegetable samples from four different sources were investigated. Vegetables analyzed are listed in Table 12. They were purchased from two markets in Bangkok Metropolitan, namely Hua Lum Pong market and Pak Klong market, and two gardens located in Sathupradit area, Bangkok Metropolitan and Suan Luang in Ampoe Kratum Band, Samut Sakorn. For each analysis, 10 g of the dry and ground sample were used and a final volume of 100 cm^3 sample solution in 1.0 M HCl was prepared. The DPP analysis of a 15.0 cm^3 aliquot sample was carried out and quantitative calculation was made by means of standard addition method. The procedure for preparation and determination were mentioned in 2.3.5 and 2.3.6, respectively. The results of DPP analyses for arsenic in various vegetables by dry ashing method are listed in Tables 13-16 and by wet digestion method are listed in Tables 17-20. The dry basis data were calculated from dry weights of vegetable samples after being dried overnight in an electric oven to remove water content. Data on the fresh basis were obtained by calculation with respect to the weights of fresh vegetables after being washed with tap water and the double deionized water, and being left in open air to evaporate the adsorbed water on their surfaces.

In cases where the peak currents were measured to be none, no addition of standard arsenite solution was performed.

Table 12 Vegetable crops analyzed in this study

Scientific name	English name	Thai name
Family Amaryllidaceae		
Allium cepa var. *aggregatum* Don.	Multiplier onion	หอมแบ่ง
Allium tuberosum Roxb	Chinese chives	กุยช่าย
Family Compositae		
Lactuca sativa Linn.	Lettuce	ผักกาดหอม
Family Convolvulaceae		
Ipomoea reptans Poir.	Chinese convolvulus	ผักบุ้งจีน
Family Cruciferae		
Brassica chinensis Linn.	Chinese cabbage	ผักกวางตุ้ง
Brassica oleracea var. *capitata*, Linn.	Cabbage	กะหล่ำปลี
Brassica oleracea var. *alboglabra* Bail.	Chinese kale	ผักกะน้า
Brassica chinensis Linn.	Chinese white cabbage	ผักกาดขาว
Family Cucurbifaceae		
Cucumis sativus Linn.	Cucumber	แตงกวา
Family Leguminosae		
Vigna sesquipedalis(L) Fruwirth.	Yard long bean	ถั่วฝักยาว
Family Umbelliferae		
Apium graveolens Linn.	Celery	คึ่นฉ่าย
Coriandrum sativum Linn.	Coriander	ผักชี

Table 13 Data for DPP analyses of arsenic in various vegetables purchased from Hua Lum Pong market by dry ashing process

Vegetable sample	i_p^* sample (μa)	i_p^* sample + standard (μa)	μg As/cm^3 added	μg As/g sample	
				Dry basis	Fresh basis
Coriander	0.37 ± 0.01	0.64 ± 0.03	0.33	2.70 ± 0.50	0.16 ± 0.03
Chinese convolvulus	0.11 ± 0.01	0.25 ± 0.06	0.20	1.80 ± 0.20	0.05 ± 0.01
Celery	0.16 ± 0.01	0.27 ± 0.01	0.13	1.60 ± 0.30	0.11 ± 0.02
Chinese chives	0.08 ± 0.01	0.15 ± 0.01	0.13	1.40 ± 0.20	0.14 ± 0.02
Lettuce	0.08 ± 0	0.17 ± 0.01	0.13	0.80 ± 0.09	0.04 ± 0
Chinese kale	0.07 ± 0.01	0.18 ± 0.02	0.13	0.75 ± 0.04	0.07 ± 0.01
Chinese white cabbage	0.09 ± 0	0.23 ± 0.01	0.07	0.66 ± 0.08	0.03 ± 0
Chinese cabbage	0.03 ± 0	0.12 ± 0.01	0.13	0.42 ± 0.06	0.02 ± 0.01
Cabbage	0.02 ± 0	0.16 ± 0.01	0.13	0.37 ± 0.03	0.03 ± 0.01
Yard long bean	0.02 ± 0.01	0.05 ± 0.01	0.07	0.28 ± 0.07	0.03 ± 0.01
Cucumber	0	(a)	(a)	none	none
Multiplier onion	0	(a)	(a)	none	none

* average peak current ± average deviation of 4 trials.
(a) standard addition was not performed.

Table 14 Data for DPP analyses of arsenic in various vegetables purchased from Pak Klong market by dry ashing process

Vegetable sample	i_p^* sample (μa)	i_p^* sample + standard (μa)	μg As/cm^3 added	μg As/ g sample	
				Dry basis	Fresh basis
Chinese convolvulus	0.09 ± 0	0.23 ± 0.01	0.33	2.01 ± 0.01	0.13 ± 0.01
Coriander	0.07 ± 0.01	0.11 ± 0.01	0.13	1.70 ± 0.30	0.09 ± 0.01
Lettuce	0.11 ± 0.01	0.26 ± 0.02	0.02	1.30 ± 0.20	0.07 ± 0.01
Celery	0.02 ± 0	0.05 ± 0	0.13	0.75 ± 0.07	0.06 ± 0.01
Chinese white cabbage	0.06 ± 0	0.16 ± 0.02	0.13	0.74 ± 0.07	0.08 ± 0.01
Chinese cabbage	0.03 ± 0.01	0.07 ± 0.01	0.08	0.58 ± 0.05	0.04 ± 0
Chinese kale	0.03 ± 0	0.04 ± 0	0.03	0.49 ± 0.09	0.04 ± 0
Multiplier onion	0.03 ± 0	0.08 ± 0.01	0.07	0.49 ± 0.09	0.04 ± 0
Cucumber	0.02 ± 0	0.04 ± 0	0.07	0.48 ± 0.07	0.02 ± 0
Yard long bean	0.02 ± 0	0.16 ± 0.01	0.27	0.34 ± 0.04	0.03 ± 0
Cabbage	0	(a)	(a)	none	none

* average peak current ± average deviation of 4 trials.

(a) standard addition was not performed.

Table 15 Data for DPP analyses of arsenic in various vegetables grown at Suan Luang garden by dry ashing process

Vegetable sample	i_p^* sample (μa)	i_p^* sample + standard(μa)	μg As/cm^3 added	μg As/ g sample	
				Dry basis	Fresh basis
Coriander	0.06 ± 0	0.11 ± 0.01	0.13	2.50 ± 0.40	0.12 ± 0.02
Lettuce	0.16 ± 0.03	0.32 ± 0.02	0.20	1.58 ± 0.03	0.08 ± 0
Chinese convolvulus	0.08 ± 0	0.19 ± 0.01	0.20	1.50 ± 0.20	0.09 ± 0.01
Celery	0.04 ± 0.01	0.08 ± 0.01	0.13	1.20 ± 0.07	0.13 ± 0.01
Chinese white cabbage	0.08 ± 0.01	0.18 ± 0.01	0.11	0.85 ± 0.07	0.04 ± 0
Chinese cabbage	0.05 ± 0	0.17 ± 0.01	0.13	0.83 ± 0.07	0.06 ± 0
Chinese kale	0.02 ± 0	0.07 ± 0.01	0.13	0.71 ±0.08	0.03 ± 0
Multiplier onion	0.03 ± 0	0.12 ± 0.01	0.27	0.66 ± 0.09	0.07 ± 0.01
Cucumber	0.03 ± 0	0.11 ± 0	0.13	0.43 ± 0.05	0.02 ± 0
Yard long bean	0.02 ± 0	0.07 ± 0.01	0.07	0.25 ± 0.04	0.03 ± 0

* average peak current ± average deviation of 4 trials.

Table 16 Data for DPP analyses of arsenic in various vegetables grown at Sathupradit garden by dry ashing process

Vegetable sample	i_p^* sample (µa)	i_p^* sample + standard (µa)	µg As/cm^3 added	µg As/ g sample	
				Dry basis	Fresh basis
Chinese convolvulus	0.07 ± 0.01	0.26 ± 0.04	0.13	2.98 ± 0.30	0.24 ± 0.04
Coriander	0.07 ± 0.01	0.13 ± 0.02	0.13	2.22 ± 0.30	0.21 ± 0.03
Celery	0.06 ± 0	0.10 ± 0.01	0.13	1.90 ± 0.40	0.17 ± 0.03
Chinese cabbage	0.03 ± 0	0.10 ± 0.01	0.27	1.35 ± 0.20	0.10 ± 0.01
Lettuce	0.05 ± 0	0.11 ± 0	0.33	1.19 ± 0.07	0.07 ± 0
Chinese white cabbage	0.07 ± 0.01	0.32 ± 0.04	0.27	0.87 ± 0.05	0.13 ± 0.01
Multiplier onion	0.05 ± 0	0.17 ± 0.01	0.08	0.35 ± 0.06	0.01 ± 0
Chinese kale	0.02 ± 0	0.07 ± 0.01	0.13	0.34 ± 0.03	0.03 ± 0
Yard long bean	0.03 ± 0	0.11 ± 0.01	0.04	0.14 ± 0.02	0.01 ± 0
Cucumber	0	(a)	(a)	none	none

* average peak current ± average deviation of 4 trials.

(a) standard addition was not performed.

Table 17 Data for DPP analyses of arsenic in various vegetables purchased from Hua Lum Pong market by wet digestion process

Vegetable sample	i_p^* sample (μa)	i_p^* sample + standard (μa)	μg As/cm^3 added	μg . As/ g sample	
				Dry basis	Fresh basis
Chinese chives	0.12 ± 0	2.34 ± 0.01	2.00	1.50 ± 0.30	0.14 ± 0.03
Coriander	0.04 ± 0	0.06 ± 0	0.05	1.20 ± 0.10	0.08 ± 0.01
Chinese convolvulus	0.06 ± 0	0.09 ± 0.01	0.07	1.18 ± 0.18	0.03 ± 0
Chinese white cabbage	0.65 ± 0	0.85 ± 0.03	0.03	0.56 ± 0.09	0.02 ± 0
Celery	0.12 ± 0	0.25 ± 0.01	0.07	0.54 ± 0.07	0.04 ± 0
Chinese kale	0.28 ± 0.02	0.59 ± 0	0.07	0.49 ± 0.03	0.05 ± 0
Lettuce	0.22 ± 0.	2,86 ± 0.09	0.20	0.23 ± 0.03	0.01 ± 0
Chinese cabbage	0.04 ± 0	0.10 ± 0	0.01	0.20 ± 0.02	0.01 ± 0
Yard long bean	0.19 ± 0	0.39 ± 0.08	0.03	0.18 ± 0	0.02 ± 0
Cabbage	0	(a)	(a)	none	none
Cucumber	0	(a)	(a)	none	none
Multiplier onion	0	(a)	(a)	none	none

* average peak current ± average deviation of 4 trials.

(a) standard addition was not performed.

Table 18 Data for DPP analyses of arsenic in various vegetables purchased from Pak Klong market by wet digestion process

Vegetable sample	i_p^* sample (μa)	i_p^* sample + standard (μa)	μg As/cm^3 added	μg As / g sample	
				Dry basis	Fresh basis
Chinese convolvulus	0.15 ± 0	0.23 ± 0	0.23	1.80 ± 0.10	0.11 ± 0.01
Coriander	0.13 ± 0	1.08 ± 0	2.00	1.50 ± 0.20	0.07 ± 0.01
Lettuce	0.09 ± 0.01	0.26 ± 0.01	0.27	1.18 ± 0.03	0.06 ± 0
Yard long bean	0.14 ± 0.02	0.26 ± 0.02	0.13	0.35 ± 0.06	0.03 ± 0
Celery	0.08 ± 0.01	0.22 ± 0.02	0.07	0.22 ± 0.02	0.02 ± 0
Cucumber	0.01 ± 0	0.03 ± 0	0.07	0.19 ± 0.02	0.08 ± 0.01
Chinese white cabbage	0.01 ± 0	0.21 ± 0.01	0.13	0.19 ± 0.02	0.08 ± 0.01
Multiplier onion	0.01 ± 0	0.06 ± 0.01	.0.07	0.18 ± 0	0.02 ± 0
Chinese kale	0.01 ± 0	0.03 ± 0.01	0.01	0.11 ± 0.01	0.01 ± 0
Chinese cabbage	0	(a)	(a)	none	none
Cabbage	0	(a)	(a)	none	none

* average peak current ± average deviation of 4 trials.

(a) standard addition was not performed.

Table 19 Data for DPP analyses of arsenic in various vegetables grown at Suan Luang garden by wet digestion process

Vegetable sample	i_p^* sample (μa)	i_p^* sample + standard (μa)	μg As/cm^3 added	μg As / g sample	
				Dry basis	Fresh basis
Coriander	0.17 ± 0	0.20 ± 0	0.04	1.58 ± 0.01	0.08 ± 0.01
Celery	0.04 ± 0.01	0.12 ± 0.01	0.02	0.86 ± 0.02	0.09 ± 0
Chinese cabbage	0.04 ± 0	0.08 ± 0.01	0.07	0.85 ± 0.04	0.06 ± 0
Chinese white cabbage	0.07 ± 0	0.16 ± 0.01	0.17	0.50 ± 0.04	0.02 ± 0
Lettuce	0.02 ± 0	0.14 ± 0.01	0.33	0.49 ± 0.02	0.03 ± 0
Chinese convolvulus	0.07 ± 0	0.10 ± 0.01	0.01	0.24 ± 0	0.01 ± 0
Chinese kale	0.07 ± 0	0.13 ± 0.01	0.01	0.17 ± 0.01	0.01 ± 0
Multiplier onion	0	(a)	(a)	none	none
Cucumber	0	(a)	(a)	none	none
Yard long bean	0	(a)	(a)	none	none

* average peak current ± average deviation of 4 trials.

(a) standard addition was not performed.

Table 20 Data for DPP analyses of arsenic in various vegetables grown at Sathupradit garden by wet digestion process

Vegetable sample	i_p^* sample (μa)	i_p^* sample + standard (μa)	μg As/cm^3 added	μg As / g sample	
				Dry basis	Fresh basis
Chinese convolvulus	0.02 ± 0	0.04 ± 0	0.07	2.65 ± 0.10	0.24 ± 0.01
Celery	0.07 ± 0.01	0.33 ± 0.06	0.33	1.60 ± 0.40	0.14 ± 0.04
Coriander	0.03 ± 0	0.08 ± 0	0.20	1.30 ± 0.12	0.12 ± 0.01
Chinese cabbage	0.03 ± 0	0.07 ±0	0.13	0.86 ± 0.04	0.07 ± 0
Lettuce	0.01 ± 0	0.03 ± 0.01	0.10	0.56 ± 0.08	0.03 ± 0
Chinese white cabbage	0.05 ± 0	0.24 ± 0.01	0.20	0.55 ± 0.04	0.08 ± 0.01
Chinese kale	0.01 ± 0	0.02 ± 0	0.04	0.21 ± 0.01	0.02 ± 0
Multiplier onion	0	(a)	(a)	none	none
Cucumber	0	(a)	(a)	none	none
Yard long bean	0	(a)	(a)	none	none

* average peak current ± average deviation of 4 trials.

(a) standard addition was not performed.

In Tables 13-20, the arsenic contents in vegetables on dry basis were arranged in the decreasing order.

According to Tables 13-16, the following conclusions about arsenic analysis with dry ashing method were obtained.

Vegetables from Hua Lum Pong market that contained the highest arsenic, 2.70 µg As/g of the dry vegetable, was coriander. Cucumber and multiplier onion were found to contain no arsenic. Other vegetables containing arsenic in the decreasing order were Chinese convolvulus, celery, Chinese chives, lettuce, Chinese kale, Chinese white cabbage, Chinese cabbage, cabbage and yard long bean. On fresh basis, coriander from this source contained 0.16 µg As/g which was also the highest amount. The decreasing order of arsenic contents in vegetables except coriander was as followed, Chinese chives, celery, Chinese kale, Chinese convolvulus, lettuce, yard long bean, cabbage, Chinese white cabbage and Chinese cabbage.

Maximum arsenic contents in various vegetables from Pak Klong market were found in Chinese convolvulus, both on dry basis (2.01 µg As/g) and fresh basis(0.13 µg As/g). No arsenic was found in cabbage. The decreasing order of vegetables in which arsenic was found on dry basis was Chinese convolvulus, coriander, lettuce, celery, Chinese white cabbage, Chinese cabbage, Chinese kale, multiplier onion, cucumber, yard long bean and cabbage. On fresh basis, vegetables were arranged in the following decreasing order;

Chinese convolvulus, coriander, Chinese white cabbage, lettuce, celery, multiplier onion, Chinese kale, Chinese cabbage, yard long bean, cucumber and cabbage.

Among the analyzed vegetables from Suan Luang garden, coriander contained the highest arsenic amount (2.50 µg As/g) on dry basis. Other vegetables containing arsenic in the decreasing order were lettuce, Chinese convolvulus, celery, Chinese white cabbage, Chinese cabbage, Chinese kale, multiplier onion, cucumber and yard long bean. On fresh basis, celery was found to contain maximum arsenic content (0.13 µg As/g). The decreasing order of arsenic contents in vegetables was as followed, celery, coriander, Chinese convolvulus, lettuce, multiplier onion, Chinese cabbage, Chinese white cabbage, Chinese kale, yard long bean and cucumber.

From Sathupradit garden, maximum arsenic contents were found in Chinese convolvulus on fresh and dry bases (0.24 µg As/g and 2.98 µg As/g, respectively) which were the maximum contents found in vegetables from four sources by dry ashing on fresh and dry bases. No arsenic was found in cucumber. On dry basis, other vegetables containing arsenic arranged in decreasing order were coriander, celery, Chinese cabbage, lettuce, Chinese white cabbage, multiplier onion, Chinese kale and yard long bean. On fresh basis, the order was differently arranged as followed, Chinese convolvulus, coriander, celery, Chinese white cabbage, Chinese cabbage, lettuce, Chinese kale, yard long bean and multiplier onion.

Owing to Tables 16-19, the following results in wet digestion could be mentioned.

The highest amount of arsenic found in vegetables purchased from Hua Lum Pong market was in Chinese chives, 1.50 μg As/g on dry basis and 0.14 μg As/g on fresh basis. Cabbage, cucumber and multiplier onion were found to contain no arsenic. The decreasing order of arsenic contents in vegetables on dry basis was as followed, Chinese chives, coriander, Chinese convolvulus, Chinese white cabbage, celery, Chinese kale, lettuce, Chinese cabbage and yard long bean. On fresh basis, the vegetables were arranged in the following decreasing order, Chinese chives, coriander, Chinese kale, celery, Chinese convolvulus, Chinese white cabbage, yard long bean, Chinese cabbage and lettuce.

Among vegetables purchased from Pak Klong market, Chinese convolvulus contained the highest amounts of arsenic. They were 1.80 ug As/g of dry weight of vegetable and 0.11 μg As/g of fresh vegetable weight. On dry basis the arsenic contents could be arranged in the following way, Chinese convolvulus, coriander, lettuce, yard long bean, celery, cucumber, Chinese white cabbage, multiplier onion and Chinese kale. No arsenic was found in Chinese cabbage and cabbage. On fresh basis, the order of arsenic contents was performed in decreasing tendency as followed, Chinese convolvulus, cucumber, Chinese white cabbage, coriander, lettuce, yard long bean, celery, multiplier onion and Chinese kale.

From Suan Luang garden, coriander appeared to contain maximum arsenic (1.58 µg As/g) on dry basis and celery contained highest arsenic amount on fresh basis (0.09 µg As/g). Cucumber, multiplier onion and yard long bean seemed to contain no arsenic. The decreasing order of arsenic contents on dry basis was as followed, coriander, celery, Chinese cabbage, Chinese white cabbage, lettuce, Chinese convolvulus and Chinese kale. Arsenic amounts as calculated on fresh basis of vegetables were arranged in the following decreasing order, celery, coriander, Chinese cabbage, lettuce, Chinese white cabbage, Chinese convolvulus, and Chinese kale.

Chinese convolvulus from Sathupradit garden was found to possess maximum arsenic value, i.e. 2.65 µg As/g of dry vegetable and 0.24 µg As/g of fresh vegetable. These amounts were the highest arsenic values found in vegetables from four sources with the wet digestion method. On dry basis, vegetables that contained arsenic in decreasing order were as followed, Chinese convolvulus, celery, coriander, Chinese cabbage, lettuce, Chinese white cabbage, Chinese kale. Cucumber, multiplier onion and yard long bean were found to contain no arsenic. On fresh basis, the order was as followed, Chinese convolvulus, celery, coriander, Chinese white cabbage, Chinese cabbage, lettuce and Chinese kale.

The orders of arsenic contents in vegetables were different on dry basis and fresh basis even for the same set of vegetables from same source. This was due to the fact that conversion factor for the dry weight to the fresh weight of each species of vegetable was not identical. Even for the same vegetable species, if the sources were different; its conversion factor was not the same (see Table 21). Conversion factors were obtained by dividing the fresh weight of vegetable (after evaporating the surface adsorbed water) by its dry weight. Therefore, this factor could be used to imply the water content in the vegetable.

Some data for cabbage and Chinese chives are absent from some sources. Chinese chives was purchased only from Hua Lum Pong market. Cabbages were from two markets since they were not grown in the gardens from where samples were taken.

4.4 Comparison between the dry ashing and the wet digestion method in determining arsenic in vegetables by DPP

In Tables 22-25, comparison of arsenic contents in vegetables between the dry ashing and the wet digestion methods are presented.

From the recovery data in Table 9 and 10, it seemed that precision by wet digestion method was better than dry ashing method. However, when both methods were

Table 21 Conversion factors for the dry weight to the fresh weight of vegetables

(g of fresh weight/ g of dry weight)

Vegetable sample	Source			
	Hua Lum Pong market	Pak Klong market	Suan Luang garden	Sathupradit garden
Cabbage	15.21	16.66	-	-
Celery	13.48	11.90	11.89	9.09
Chinese cabbage	18.02	16.21	13.14	14.35
Chinese chives	10.59	-	-	-
Chinese convolvulus	17.60	15.89	11.04	16.99
Chinese kale	10.19	13.85	11.68	17.60
Chinese white cabbage	24.80	20.50	27.78	22.71
Coriander	16.29	20.56	20.77	21.00
Cucumber	22.82	23.94	21.63	19.48
Lettuce	21.81	18.83	17.35	19.28
Multiplier onion	13.86	12.35	17.78	15.36
Yard long bean	22.82	23.94	21.63	17.48

Table 22 Comparison of arsenic contents in the vegetables purchased from Hua Lum Pong market by dry ashing and wet digestion methods

Vegetable sample	Dry ashing (µg As/ g sample)		Wet digestion (µg As/ g sample)	
	Dry basis	Fresh basis	Dry basis	Fresh basis
Cabbage	0.37 ± 0.03	0.03 ± 0.01	none	none
Celery	1.60 ± 0.30	0.11 ± 0.02	0.54 ± 0.07	0.04 ± 0
Chinese cabbage	0.42 ± 0.06	0.02 ± 0	0.20 ± 0.02	0.01 ± 0
Chinese chives	1.40 ± 0.20	0.14 ± 0.02	1.50 ± 0.30	0.14 ± 0.03
Chinese convolvulus	1.80 ± 0.20	0.05 ± 0.01	1.18 ± 0.18	0.03 ± 0
Chinese kale	0.75 ± 0.04	0.07 ± 0.01	0.49 ± 0.03	0.05 ± 0
Chinese white cabbage	0.66 ± 0.08	0.03 ± 0	0.56 ± 0.09	0.02 ± 0
Coriander	2.70 ± 0.50	0.16 ± 0.03	1.20 ± 0.10	0.08 ± 0.01
Cucumber	none	none	none	none
Lettuce	0.80 ± 0.09	0.04 ± 0	0.23 ± 0.03	0.01 ± 0
Multiplier onion	none	none	none	none
Yard long bean	0.28 ± 0.07	0.03 ± 0	0.18 ± 0	0.02 ± 0

Table 23 Comparison of arsenic contents in the vegetables purchased from Pak Klong market by dry ashing and wet digestion methods

Vegetable sample	Dry ashing (µg As/ g sample)		Wet digestion (µg As/g sample)	
	Dry basis	Fresh basis	Dry basis	Fresh basis
Cabbage	none	none	none	none
Celery	0.75 ± 0.07	0.06 ± 0.01	0.22 ±0.02	0.02 ± 0
Chinese cabbage	0.58 ± 0.05	0.04 ± 0.	none	none
Chinese convolvulus	2.01 ± 0.01	0.13 ± 0.01	1.80 ± 0.10	0.11 ± 0.01
Chinese kale	0.49 ± 0.09	0.04 ± 0.01	0.11 ± 0.01	0.01 ± 0
Chinese white cabbage	0.74 ± 0.07	0.08 ± 0.01	0.19 ± 0.02	0.08 ± 0.01
Coriander	1.70 ± 0.30	0.09 ± 0.01	1.50 ± 0.20	0.07 ± 0.01
Cucumber	0.48 ± 0.07	0.02 ± 0	0.19 ± 0.02	0.08 ± 0.01
Lettuce	1.30 ± 0.20	0.07 ± 0.01	1.18 ± 0.03	0.06 ± 0
Multiplier onion	0.49 ± 0.09	0.04 ± 0.01	0.18 ± 0	0.02 ± 0
Yard long bean	0.34 ± 0.04	0.03 ± 0	0.35 ± 0.06	0.03 ± 0

Table 24 Comparison of arsenic contents in the vegetables grown in Sathupradit garden by dry ashing and wet digestion methods

Vegetable sample	Dry ashing (μg As / g sample)		Wet digestion (μg As / g sample)	
	Dry basis	fresh basis	Dry basis	Fresh basis
Celery	1.90 ± 0.40	0.17 ± 0.03	1.60 ± 0.40	0.14 ± 0.04
Chinese cabbage	1.35 ± 0.20	0.10 ± 0.01	0.86 ± 0.04	0.07 ± 0
Chinese convolvulus	2.98 ± 0.30	0.24 ± 0.04	2.65 ± 0.10	0.24 ± 0.01
Chinese kale	0.34 ± 0.03	0.03 ± 0	0.21 ± 0.01	0.02 ± 0
Chinese white cabbage	0.87 ±0.05	0.13 ± 0.01	0.55 ± 0.04	0.08 ± 0.01
Coriander	2.22 ± 0.30	0.21 ± 0.03	1.30 ± 0.12	0.12 ± 0.01
Cucumber	none	none	none	none
Lettuce	1.19 ± 0.07	0.07 ± 0	0.56 ± 0.08	0.03 ± 0
Multiplier onion	0.35 ± 0.06	0.01 ± 0	none	none
Yard long bean	0.14 ± 0.02	0.01 ± 0	none	none

Table 25 Comparison of arsenic contents in the vegetables grown in Suan Luang garden by dry ashing and wet digestion methods

Vegetable sample	Dry ashing (µg As / g sample)		Wet digestion (µg As / g sample)	
	Dry basis	Fresh basis	Dry basis	Fresh basis
Celery	1.20 ± 0.07	0.13 ± 0.01	0.86 ± 0.02	0.09 ± 0
Chinese cabbage	0.83 ± 0.07	0.06 ± 0.	0.85 ± 0.04	0.06 ± 0
Chinese convolvulus	1.50 ± 0.20	0.09 ± 0.01	0.24 ± 0	0.01 ± 0
Chinese kale	0.71 ± 0.08	0.03 ± 0	0.17 ± 0.01	0.01 ± 0
Chinese white cabbage	0.85 ± 0.07	0.04 ± 0	0.50 ± 0.04	0.02 ± 0
Coriander	2.50 ± 0.40	0.12 ± 0.02	1.58 ± 0.01	0.08 ± 0.01
Lettuce	1.58 ±0.03	0.08 ± 0	0.49 ± 0.02	0.03 ± 0
Multiplier onion	0.66 ± 0.09	0.07 ± 0.01	nono	none
Cucumber	0.43 ± 0.05	0.02 ± 0	none	none
Yard long bean	0.25 ± 0.04	0.03 ± 0	none	none

applied to the analyses of arsenic in various vegetables, the results seemed to reverse. As described by Diamondstone and Burke (26), partial oxidation of As (III) in vegetable samples led to lower arsenic contents.

From recovery results and Tables 22-25, it was clearly seen that dry ashing process yielded more arsenic content than wet digestion did. In comparison, dry ashing needed less attention of the analyst and less precaution. In addition, larger amount of sample could be employed so the sensitivity was increased. Whereas in wet digestion process, the larger the amount of sample used, the longer time it took and the larger the amount of reagent needed. Precaution was necessary in wet digestion in many steps. For examples, if the digestion mixture is dried out while the organic matter are not completely decomposed, charring and loss of arsenic due to sublimation can involve (65). The Kjeldahl digestion flask should be allowed to cool before each addition of acid or it would crack. For the same quantity of sample, wet digestion required for longer period of time. Duration of digestion by acid varied from species to species of vegetables depending on organic content in vegetable (ca. 8 hours to 10 hours).

From the data previously shown, it can be seen that As (III) contents in vegetables vary from species to species. The variation also depends on the places where samples were taken from, and methods of organic matter decomposition. Owing to the latter factor, the amounts of arsenic found in dry ashing were higher than in wet digestion with acid. The content of arsenic in a vegetable is influenced by available soil arsenic, species and parts of the vegetables analyzed. Absorption of arsenic in soil varies with clay content, composition of other elements, such as Fe, Al in soil (5,9). Applications of fertilizers and pesticides increase arsenic quantity in soil and also in vegetable. Uptake of arsenic in various parts of a vegetable is different. The highest levels of arsenic are found in plant roots, the vegetative top growth is intermediate, edible seeds and fruits contain the lowest level of arsenic (5,8).

From preceding data, Chinese convolvulus contained high arsenic content as well as coriander and celery. Chinese convolvulus was planted on water surface where absorption of arsenic from water was easy and rapid. Both coriander and celery belong to the same family, Umbelliferae. In case of coriander, root parts were included in the sample analysis and root can absorb arsenic very well (5) and as a result the arsenic content in coriander was high. Even Chinese convolvulus was found to contain the highest arsenic content, 0.24 µg As/g of the fresh vegetable, this value is still less than the tolerance limits on fresh basis as allowed by many countries, such as 2.60 µg As/g of the vegetable by U.S. (5), 1.50 µg As/g sample by

Australia (66), 1.00 µg As/g sample by Canada (66) and France (67), and 0.76 µg As/g of vegetable by Japan (67). Multiplier onion, the monocotyledon plant, retained rather low level of arsenic. Cucumber and yard long bean, of which fruits and seeds are edible, also contained small amount of arsenic.