J Nutr Sci Vitaminol, **50**, 203–210, 2004

The Polyphenol Content and Antioxidant Activities of the Main Edible Vegetables in Northern Vietnam

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(Received November 20, 2003)

Summary Oxidized low-density lipoprotein (LDL) is considered a risk factor in atherosclerosis, and polyphenols are the potential agents to inhibit the oxidation of LDL. We determined the polyphenol contents and the antioxidant activities of commonly consumed vegetables in Vietnam and assessed the quantity of the polyphenol intake from vegetables in the current Vietnamese diet. The polyphenol contents in 30 kinds of vegetables was determined by the Folin-Ciocalteu method. The antioxidant activities of vegetables were evaluated by measuring the oxidation of LDL and the reduction of the 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical. In this study, some herbs and edible wild vegetables possessed high contents of polyphenols and antioxidant activities. Among green vegetables, sweet potato leaves showed both a high polyphenol content and antioxidant activity. The mean polyphenol daily intake of the Vietnamese was a 595 mg catechin equivalent. Water spinach, a kind of green vegetable, contributed the highest amount (45%) of the total polyphenol intake, followed by other green vegetables. Neither herbs nor edible wild vegetables contributed significantly to the total polyphenol intake due to their low consumption. Green vegetables are therefore considered very important sources of polyphenol intake for the Vietnamese.

Key Words polyphenol, antioxidant, vegetable, Vietnamese, LDL oxidation

The important roles of vegetables and fruits in health have been recognized in many studies. Associations between the high consumption of vegetables and fruits and a low risk of cardiovascular diseases have been reported (*1–5*). Since the Zutphen Elderly Study (*6*) showed an inverse relation between the flavonoids intake and cardiovascular disease mortality, much attention has been given to the roles of polyphenols in vegetables and fruits (*7–9*). Polyphenols are abundant antioxidants in our diets and may protect the tissues in the body against oxidative stress and decrease the risk of cardiovascular diseases (*8, 9*).

In the big cities of Vietnam, the prevalence of cardiovascular diseases has recently increased along with changes in lifestyles and dietary patterns (*10–13*). The oxidation of low-density cholesterol (LDL) which is considered crucial in atherosclerosis can be inhibited by polyphenols in vegetables. Vegetables, which are a main contributor in the Vietnamese diet might contain a protective agent for atherosclerosis like polyphenols. However, there has so far been no study on the content of polyphenols in Vietnamese vegetables. This study was carried out to measure the content of polyphenols and the antioxidant activities of Vietnamese vegetables and to estimate the intake quantity of polyphenols from vegetables in the diet of northern Vietnamese.

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MATERIALS AND METHODS

Sample preparation. Thirty kinds of commonly consumed vegetables including nine kinds of herbs, four kinds of edible wild vegetables, ten kinds of dark green vegetables, and seven other vegetables were selected from the Vietnamese Food and Composition Table (*14*). The names of the samples are given mostly in English and Vietnamese (only the vegetables with unknown English names are given in Latin) (Table 1). These vegetables were purchased from local markets and were then cleaned and lyophilized. The weights of the vegetables were measured before and after freeze-drying. The lyophilisate was then ground into a fine powder and stored at −20°C until used (*15*).

Extraction. Total polyphenol content of the vegetable was defined as a quantity of polyphenol obtained after the hydrolysis of glycosides by HCl and the free "unconjugated" polyphenol was the quantity without hydrolysis (*15, 16*). One hundred milligrams of dry sample was stirred for 2 h at 90°C with 5 mL of 50%

Table 1. Names of herbs and vegetables used in the experiment.

Latin names	English names	(*Vietnamese names*)
Herbs (9)		
Polygonum odoratum	Smartweed	(*Rau ram*)
Ocimum basilsum L.	Basil sweet	(*Rau hung*)
Perilla frutescens	Beefsteak	(*Tia to*)
Limnophila aromatic	Finger grass	(*Rau ngo*)
Polygonum aviculare	Herb	(*Rau dang*)
Schizonepeta tenuifolia	Sweet marjoram	(*Kinh gioi*)
Eryngium foetidum	Long coriander	(*Mui tau*)
Anethum graveolens L.	Dill	(*Thi la*)
Coriandrum salivum L.	Coriander	(*Rau mui*)
Edible wild vegetables (4)		
Centella asiatica	Wild plant	(*Rau ma*)
Houttuynia cordata	Fishwort	(*Dap ca*)
Peristrophe roxburghiana	Wild plant	(*La cam*)
Paederia tomentosa	Wild plant	(*La mo*)
Dark green vegetables (10)		
Ipomoea batatas	Sweet potato leaves	(*Rau lang*)
Corhorus olitorius	Jute potherb	(*Rau day*)
Pipet lolot C. DC	Edible herbaceous plant	(*La lot*)
Sauropus androgynus	Sauropus leaves	(*Rau ngot*)
Blumea myriocephala DC.	Edible herbaceous plant	(*Xuong song*)
Amaranthus hypochondriacus	Amaranth	(*Rau den*)
Ipomoea aquatica	Water spinach	(*Rau muong*)
Cucurbita pepo	Pumpkin leaves	(*Rau bi*)
Nasturtium offcinale	Water cress	(*Cai soong*)
Chrysanthemum coronatium	Chrysanthemum	(*Cai cuc*)
Other vegetables (7)		
Brassica oleracea	Cabbage	(*Bap cai*)
Telosma cordata	Pergularia	(*Thien ly*)
Vigna sesquipedalis	Asparagus bean	(*Dau dua*)
Lactuca sativa L.	Lettuce	(*Rau xa lach*)
Allium cepa	Onion	(*Hanh*)
Momordica charantia	Balsam pear	(*Muop dang*)
Bambusa spp.	Bamboo shoot	(*Mang*)

aqueous methanol to determine the free polyphenol content or 50% aqueous methanol and 1.2 M HCl for a total polyphenol analysis and then were centrifuged for 15 min at 4°C. The extraction was filtered with a 0.45 μm filter and the materials were all used within the same day to analyze the polyphenol content and the antioxidant activities (*16*).

Total polyphenols content. The total polyphenol and free polyphenol contents were determined by the Folin-Ciocalteu colorimetric method using catechin as a standard (*17*). Catechin was purchased from Sigma (St. Louis, MO, USA). This standard was dissolved in 50% aqueous methanol until a concentration of 1 mg/mL was obtained for use. The polyphenol content of the fresh edible part of the vegetable was calculated as the catechin equivalent.

Free-radical scavenging activity. The free-radical scavenging activity was determined using a spectrophotometer to measure the reduction of the 1,1-diphenyl-2-picrylhydrazyl radical (DPPH) (Wako Pure Chemical Industries, Ltd, Osaka, Japan) (*18*). An aliquot containing the extract from each vegetable was mixed with 2 mL of 0.1 mM DPPH in ethanol. Following 20 min of incubation at 37°C, the absorbance was measured at 516 nm. The free-radical scavenging activity of all kinds of vegetables was expressed as the ascorbic acid concentration (mM) to decrease the initial DPPH radical absorbance by 50%. The antiradical activity of polyphenols in vegetables was defined as the amount of polyphenol necessary to decrease the initial DPPH concentration by 50% (efficient concentration=EC_{50}) (*19*).

The LDL oxidation inhibition. The fasting serum of a normolipidemic volunteer with the informed consent, was taken and diluted with KBr to the density of 1.063, and was then separated by single-spin density gradient ultracentrifugation (417,000×*g*, 40 min, 4°C) with a TLA 100.4 rotor fixed-angle rotor (Beckman Instruments Inc., CA, USA) (*20*). The isolated LDL was taken and diluted with phosphate-buffered saline (PBS) solution to produce a final LDL-protein concentration of 70 μg/mL (*21*). A 2,2′-azobis(4-methozy-2,4-dimethylvaleronitrile) (AMVN-CH_3O) solution was diluted to a final concentration of 400 μM, then 5 μL samples were added to the LDL solutions. The kinetics of the LDL oxidation were measured by monitoring the changes in the conjugated diene formation at 234 nm absorbance

Table 2. Polyphenol content in vegetables.

Vegetables		Total polyphenol (μmol catechin/g) (in fresh edible part)	Free polyphenols (μmol catechin/g) (in fresh edible part)	Percentage of free polyphenols
English/Latin	(*Vietnamese*)			
Herbs				
Smartweed	(*Rau ram*)	52.5±3.9	37.9±2.5	72.5±5.2
Basil sweet	(*Rau hung*)	41.0±1.2	25.3±0.4	61.8±2.6
Beefsteak	(*Tia to*)	35.8±0.8	23.3±0.5	65.3±1.4
Finger grass	(*Rau ngo*)	30.7±2.8	22.8±0.2	74.8±6.9
Polygonum aviculare	(*Rau dang*)	28.1±1.6	19.7±1.3	70.2±5.4
Sweet marjoram	(*Kinh gioi*)	23.0±0.9	14.5±0.2	63.4±3.1
Dill	(*Thi la*)	13.6±0.9	9.0±0.3	66.6±6.2
Long coriander	(*Mui tau*)	13.3±0.8	7.7±0.4	57.6±3.8
Coriander	(*Rau mui*)	10.2±0.1	5.4±0.3	52.7±2.9
Edible wild vegetables				
Centella asiatica	(*Rau ma*)	44.7±2.9	29.0±0.5	65.0±4.8
Fishwort	(*Dap ca*)	31.5±0.3	22.6±0.4	71.7±0.9
Peristrophe roxburghiana	(*La cam*)	17.7±0.6	11.5±0.6	65.7±1.9
Paederia tomentosa	(*La mo*)	17.7±1.2	13.6±0.3	77.2±4.0
Dark green vegetables				
Jute potherb	(*Rau day*)	30.9±0.8	17.9±0.9	57.8±1.7
Pipet lolot C. DC	(*La lot*)	30.5±0.3	16.3±0.7	53.6±2.7
Sweet potato leaves	(*Rau lang*)	30.3±0.6	23.6±0.2	78.0±1.9
Blumea myriocephala DC.	(*Xuong song*)	22.1±0.3	14.1±0.2	64.0±1.3
Sauropus leaves	(*Rau ngot*)	19.9±0.2	13.0±0.7	65.1±3.2
Pumpkin leaves	(*Rau bi*)	19.7±2.4	11.9±0.8	61.4±11.5
Amaranth	(*Rau den*)	15.0±0.4	10.5±0.6	70.1±5.2
Water spinach	(*Rau muong*)	10.9±0.5	6.9±0.2	63.3±4.1
Water cress	(*Cai soong*)	8.1±0.2	1.0±0.2	63.5±0.2
Chrysanthemum	(*Cai cuc*)	7.7±0.2	2.9±0.1	37.3±2.2
Other vegetables				
Pergularia	(*Thien ly*)	11.1±2.2	7.3±0.2	68.0±13.2
Asparagus bean	(*Dau dua*)	9.2±1.2	4.6±0.1	50.3±5.8
Bamboo shoot	(*Mang*)	7.5±0.3	4.8±0.1	64.4±3.1
Onion	(*Hanh*)	5.1±0.1	2.0±0.0	38.9±0.8
Lettuce	(*Rau xa lach*)	3.6±0.0	1.0±0.0	27.1±0.8
Cabbage	(*Bap cai*)	2.8±0.0	1.0±0.1	37.3±3.4
Balsam pear	(*Muop dang*)	2.7±0.1	1.3±0.2	49.3±8.6

recording at 5-min-intervals at 37°C (*22*). The lag-phase, defined as the time period between the addition of AMVN-CH_3O and the start of the propagation period, is considered to reflect the susceptibility of LDL to oxidative modification, measured as previously described (*23*). The inhibition of the LDL oxidation of each vegetable was expressed as the LDL lag time prolongation rate in comparison with a control. Similar to the DPPH experiment, the amount of polyphenols (as μmol catechin) needed to obtain a 50% inhibition of LDL oxidation (IC_{50}) was determined (*16*). In order to compare the relative antioxidant activities of polyphenols in the inhibition of LDL oxidation, the polyphenol antioxidant index ($PAOXI_{lagtime}$) was also calculated. The formula used was as follows (*16*):

$$PAOXI_{lagtime} = \frac{\text{polyphenols content (}\mu\text{mol catechin/g)}}{IC_{50}\ (\mu\text{mol})}$$

Similarly, the polyphenol antioxidant index in DPPH experiment ($PAOXI_{DPPH}$) was determined by dividing the polyphenol content by the EC_{50} in the same unit as follows:

$$PAOXI_{DPPH} = \frac{\text{polyphenols content (}\mu\text{mol catechin/g)}}{EC_{50}\ (\mu\text{mol})}$$

Polyphenol intake from vegetables. The data on the polyphenol content of the vegetables was applied to estimate the polyphenol intake (equivalent to catechin) from vegetables in a nutritional survey of 289 individuals from northern Vietnam. The mean age and body mass index (BMI) of the subjects was 44±16 (y) and 20±3 (kg/m^2), respectively.

Statistical analysis. The data are expressed as the mean values±SD. A statistical analysis was conducted using the StatView 5.0 software package (SAS Institute Inc., Cary, NC, USA). The correlation coefficients were calculated between the polyphenols content and the antioxidant activities of vegetables in terms of the free radical scavenging activities and the LDL oxidation inhibition activities. Statistical significance was considered to exist at a value of $p<0.05$.

Table 3. The free-radical scavenging activity of vegetables based on DPPH experiment.

Vegetables		EC_{50} (nmol)	$PAOXI_{DPPH}$
English/Latin	(*Vietnamese*)	(in fresh edible part)	(in fresh edible part)
Herbs			
Finger grass	(*Rau ngo*)	3.1	737.5
Beefsteak	(*Tia to*)	4.1	693.5
Smartweed	(*Rau ram*)	4.7	666.7
Basil sweet	(*Rau hung*)	4.7	544.7
Polygonum aviculare	(*Rau dang*)	3.1	344.8
Sweet marjoram	(*Kinh gioi*)	8.0	204.9
Dill	(*Thi la*)	5.1	178.6
Long coriander	(*Mui tau*)	8.0	135.5
Coriander	(*Rau mui*)	4.5	120.2
Edible wild vegetables			
Centella asiatica	(*Rau ma*)	3.1	595.2
Fishwort	(*Dap ca*)	4.2	537.6
Paederia tomentosa	(*La mo*)	5.2	260.4
Peristrophe roxburghiana	(*La cam*)	10.0	114.7
Dark green vegetables			
Sweet potato leaves	(*Rau lang*)	4.0	595.2
Blumea myriocephala DC.	(*Xuong song*)	4.1	344.8
Jute potherb	(*Rau day*)	6.3	239.2
Amaranth	(*Rau den*)	4.9	216.5
Pipet lolot C. DC	(*La lot*)	8.0	203.3
Water cress	(*Cai soong*)	2.6	198.4
Water spinach	(*Rau muong*)	3.7	185.9
Pumpkin leaves	(*Rau bi*)	7.0	170.1
Sauropus leaves	(*Rau ngot*)	8.5	157.7
Chrysanthemum	(*Cai cuc*)	2.4	117.4
Other vegetables			
Pergularia	(*Thien ly*)	5.4	134.8
Asparagus bean	(*Dau dua*)	3.5	133.0
Lettuce	(*Rau xa lach*)	2.3	24.8
Cabbage	(*Bap cai*)	3.6	24.3
Balsam pear	(*Muop dang*)	6.1	22.0
Onion	(*Hanh*)	9.9	20.2
Bamboo shoot	(*Mang*)	36.3	13.2

EC_{50}: The content of polyphenols (as catechin) in the extract to decrease the initial DPPH absorbance by 50%.
$PAOXI_{DPPH}$: Polyphenol antioxidant index in free radical scavenging.

RESULTS

The quantity of polyphenols in vegetables

The total and free polyphenol contents of 30 commonly consumed vegetables are shown in Table 2. Among the herbs group, the highest polyphenols content belonged to smartweed (equivalent to 52.5 μmol catechin/g) while the lowest polyphenols content belonged to corriander (10.2 μmol catechin/g). The polyphenol contents of four kinds of edible wild vegetables ranged from 17.7 μmol catechin/g (paeria tomentosa) to 44.7 μmol catechin/g (centella asiatica). The jute potherb, pipet lolot C. DC and sweet potato leaves contained a high content of polyphenols (approximately 31 μmol catechin/g) in dark green and other vegetables, while balsam pear had the lowest polyphenol content (2.7 μmol catechin/g). The percentage of free polyphenols content against total polyphenols content was more than 50% except for chrysanthemum, onion, lettuce, cabbage and balsam pear.

The free-radical scavenging capacity of polyphenols in vegetables

To evaluate the free-radical scavenging activity of polyphenols in vegetables, we used a method to measure the reduction of DPPH radical. The free-radical scavenging capacity of polyphenols in vegetables was expressed in the indices called EC_{50} and $PAOXI_{DPPH}$ (Table 3). The higher $PAOXI_{DPPH}$ these vegetables had, the better their antioxidant capacity. In this study, the $PAOXI_{DPPH}$ of herbs ranged from 120.2 in coriander to 737.5 in finger grass while the $PAOXI_{DPPH}$ of edible wild vegetables ranged from 114.7 in peristrophe roxburghiana to 595.2 in centella asiatica. The $PAOXI_{DPPH}$ of dark green and the other vegetables was the highest in sweet potato leaves (595.2), and the lowest in bamboo shoots (13.2). The herbs with the lowest value of EC_{50} were finger grass and polygonum aviculare (3.1 nmol). Among edible wild vegetables, centella asi-

Table 4. The inhibition of LDL oxidation in vegetables.

Vegetables		IC_{50} (nmol) (in fresh edible part)		$PAOXI_{lagtime}$ (in fresh edible part)	
English/Latin	(*Vietnamese*)	Total	Free	Total	Free
Herbs					
Finger grass	(*Rau ngo*)	10.7	27.5	2.86	0.83
Beefsteak	(*Tia to*)	18.3	26.8	2.05	1.05
Basil sweet	(*Rau hung*)	27.3	43.7	1.52	0.59
Polygonum aviculare	(*Rau dang*)	10.1	14.6	1.49	0.72
Sweet marjoram	(*Kinh gioi*)	18.8	47.0	1.38	0.35
Smartweed	(*Rau ram*)	36.8	35.7	1.18	0.88
Long coriander	(*Mui tau*)	30.7	65.7	0.62	0.17
Coriander	(*Rau mui*)	21.3	21.8	0.48	0.25
Dill	(*Thi la*)	33.2	48.8	0.41	0.19
Edible wild vegetables					
Centella asiatica	(*Rau ma*)	12.8	33.6	2.23	0.55
Fishwort	(*Dap ca*)	31.2	28.7	1.01	0.79
Paederia tomentosa	(*La mo*)	26.8	40.0	0.66	0.34
Peristrophe roxburghiana	(*La cam*)	34.3	44.9	0.52	0.26
Dark green vegetables					
Sweet potato leaves	(*Rau lang*)	19.8	29.5	1.53	0.80
Blumea myriocephala DC.	(*Xuong song*)	20.0	32.5	1.11	0.44
Water cress	(*Cai soong*)	25.7	30.0	0.78	0.46
Jute potherb	(*Rau day*)	34.9	34.2	0.75	0.44
Water spinach	(*Rau muong*)	18.9	38.4	0.58	0.18
Chrysanthemum	(*Cai cuc*)	13.2	20.0	0.58	0.14
Sauropus leaves	(*Rau ngot*)	41.7	61.6	0.49	0.22
Pumpkin leaves	(*Rau bi*)	42.3	44.8	0.47	0.27
Pipet lolot C. DC	(*La lot*)	75.0	46.1	0.41	0.36
Amaranth	(*Rau den*)	36.3	45.7	0.41	0.23
Other vegetables					
Pergularia	(*Thien ly*)	25.5	36.2	0.44	0.20
Asparagus bean	(*Dau dua*)	48.7	27.1	0.19	0.17
Bamboo shoot	(*Mang*)	41.6	48.1	0.18	0.10
Lettuce	(*Rau xa lach*)	13.4	22.8	0.16	0.03
Onion	(*Hanh*)	44.5	66.4	0.12	0.03
Cabbage	(*Bap cai*)	22.1	21.1	0.10	0.04
Balsam pear	(*Muop dang*)	36.5	38.4	0.08	0.04

IC_{50}: The amount of polyphenols (as catechin) needed to obtain a 50% inhibition of oxidized LDL.
$PAOXI_{lagtime}$: Polyphenol antioxidant index in inhibition oxidized LDL.

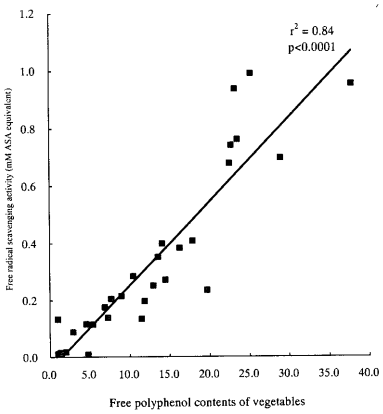

Fig. 1. The correlation between the free polyphenol content and the free radical scavenging activities of vegetables (n=30). The values are equivalent to catechin μmol in fresh edible part of vegetables.

atica possessed the lowest values of EC_{50} (3.1 nmol). Chrysanthemum and water cress had the lowest EC_{50} (2.4 and 2.6 nmol, respectively) in the group of dark green and other vegetables.

The correlation (r^2=0.84, n=30, p<0.0001) between the free radical scavenging activity of vegetables (equivalent to ascorbic acid concentration) and the free polyphenol content is shown in Fig. 1.

The inhibition of LDL oxidation of polyphenols in vegetables

The antioxidant activities of both total and free polyphenols in the vegetables to inhibit LDL oxidation in vitro (expressed as IC_{50} and $PAOXI_{lagtime}$) are given in Table 4. In the herb group, finger grass possessed the highest value of $PAOXI_{lagtime}$ in terms of total polyphenols (2.86) and beefsteak possessed a high value of $PAOXI_{lagtime}$ (2.05). Centella asiatica, a kind of edible wild vegetable, had the second highest antioxidant

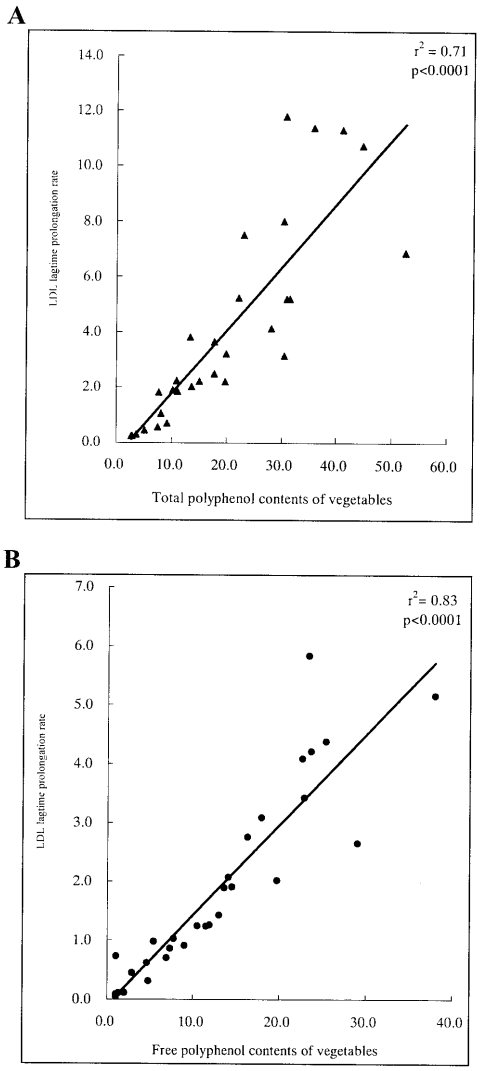

Fig. 2. The correlation between the total (A), free polyphenol content (B) and the LDL lag time prolongation rate of vegetables (n=30). The values are equivalent to catechin μmol in fresh edible part of vegetables.

activities in terms of total polyphenols ($PAOXI_{lagtime}$= 2.23). Among dark green and the other vegetables, sweet potato leaves had the highest $PAOXI_{lagtime}$ level in both total and free polyphenols. The lower the IC_{50} level, the stronger the antioxidant activities of the vegetables. Similar to the results of DPPH experiment, the lowest IC_{50} level of herbs belonged to polygonum aviculare (10.1 nmol) and finger grass (10.7 nmol) and centella asiatica had the lowest IC_{50} level (12.8 nmol) in the group of edible wild vegetables. Among dark green and the other vegetables, chrysanthemum had the lowest IC_{50} value (13.2 nmol).

Figures 2A and B show the correlation between the LDL lag time prolongation rate and the total (r^2=0.71, n=30, p<0.0001), and free polyphenol contents of the vegetables (r^2=0.83, n=30, p<0.0001).

Polyphenol intake from vegetables in the Vietnamese diet

The polyphenol content of vegetables were used to calculate the total intake of polyphenols from vegetables in the diet of 289 Vietnamese people. The results

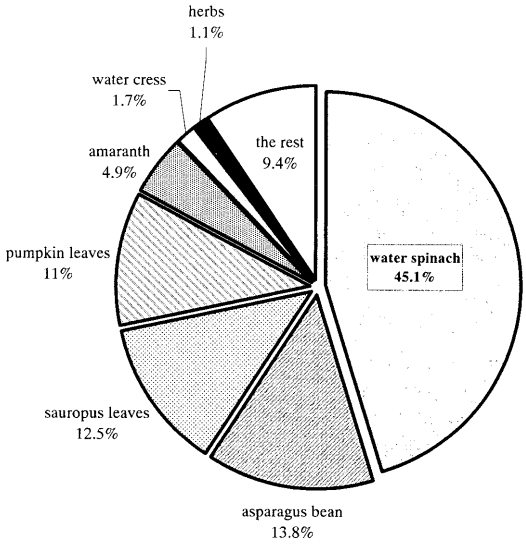

Fig. 3. The proportion of polyphenol intake from each vegetable in the Vietnamese diet. Total polyphenol intake from vegetables are 595 mg catechin.

showed that the polyphenol intake from vegetables was equivalent to 595 mg of catechin. The percentage of polyphenol intake for each vegetable is shown in Fig. 3. Regarding the polyphenol intake from vegetables of this Vietnamese population, 45.1% came from water spinach and only 1.1% came from herbs. In addition, other important sources of polyphenol intake are other green vegetables such as asparagus beans (13.8%), sauropus leaves (12.5%) and pumpkin leaves (11%).

DISCUSSION

Antioxidants may protect the tissues against free-radical initiated damage and protect LDL from oxidation. Since oxidized LDL is thought to be involved in the initial arterial injury and the formation of the fibrous plaque, protection by antioxidants as polyphenols in vegetables has a great potential in the prevention of cardiovascular diseases. This study is the first report to measure the polyphenol contents and the antioxidant activities of commonly consumed vegetables in the Vietnamese diet.

The antioxidant activities of herbs were strong for both the free radical scavenging activities and for inhibiting the LDL oxidation, and the reason for this is likely due to their high polyphenol content. The polyphenol content in one particular herb (smartweed) was approximately five times that in water spinach, which is the most frequently consumed green vegetable in the Vietnamese diet. The high content of polyphenols in herbs was in accordance with the findings of other studies in Japan and Denmark (*24, 25*). In the study in Japan, the total polyphenol concentration of 59 plant foods determined by HPLC showed that herbs such as parsley, celery, peppermint, sage, oregano and thyme contained high levels of aglycon of flavones and flavonols (*24*). The Denmark study also showed that some herbs are excellent sources of flavonoids. Quercetin and

kaemferol were the most widespread flavonoids as they were found in half of all herb samples (25). Two kinds of edible wild vegetables (centella asiatica and fishwort) proved to be high in both polyphenol quantity and antioxidant capacities in our study. Regarding the polyphenol content in wild vegetables, our findings were also in agreement with those of a Greek study using HPLC which indicated that the edible wild greens in their study had a very high flavonol content compared to the regular fresh vegetables and fruits commonly consumed in Europe. The prominent flavonol in their wild greens was quercetin, followed by kaemferol (26). Among our examined vegetables, some kinds of dark green vegetables such as sweet potato leaves, jute potherb, sauropus leaves, pumpkin leaves, amaranth and water spinach were strong in both the quality and the quantity of the polyphenol content. Moreover, the correlation between the polyphenol content and the antioxidant activities of vegetables was high, thus indicating that the antioxidant activities of these vegetables may depend on their polyphenol contents. Similarly, an American study on the antioxidant activities of 22 common vegetables using an automated oxygen radical absorbance capacity (ORAC) assay, also stated that the antioxidant capacity of vegetables depends on the amount of flavonoids that each vegetable possesses (27).

The polyphenol intake from vegetables was higher in Vietnamese than in Americans determined by the same method (595 mg equivalent to catechin in Vietnamese while 218 mg in American) (16). This might be due to differences in the eating habits and the characteristics of vegetables between the two countries. In the Vietnamese diet, rice and vegetables are the main foods. We found a high polyphenol content in Vietnamese herbs and edible wild vegetables. However, the low quantity of herb consumption led to its limited contribution to the polyphenol intake in this population (only 1.1% of total polyphenol intake). This situation was similar to that observed in Denmark, where herbs do not contribute greatly to the average flavonoid intake because the consumption of fresh herbs is seasonal, namely, only in summer (25). In Vietnam, edible wild vegetables are consumed locally, seasonally as drinks in summer, are eaten as herbs or are used as traditional medicines, therefore these edible wild vegetables are also underutilized. Nevertheless, in Greece, the healthiness of the Mediterranean diet has been attributed to its high consumption of edible wild vegetables (26). This study also showed that although the polyphenol contents of dark green vegetables were much lower than those of herbs, the polyphenol intake from vegetables in the Vietnamese diet mainly came from a high consumption of green vegetables like water spinach, sauropus leaves and pumpkin leaves.

In conclusion, a large amount of polyphenols was found in Vietnamese vegetables, especially in herbs and edible wild vegetables. However, the main source of polyphenol intake came from dark green vegetables. The high content of polyphenols as well as other antioxidants such as vitamin C, vitamin E and β-carotene in some Vietnamese vegetables and their potential importance in the prevention of atherosclerosis still require further study in the future.

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