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ScienceDirect
Food Chemistry 101 (2007) 1598–1605
Food Chemistry
www.elsevier.com/locate/foodchem

Carotenoid composition and vitamin A activity of medicinally important green leafy vegetables

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Received 22 October 2005; received in revised form 24 March 2006; accepted 12 April 2006

Abstract

Carotenoid composition of green leafy vegetables (GLVs, $n = 30$) with medicinal value was analyzed by HPLC; vitamin A activity (as retinol equivalent, RE) of provitamin A carotenoids was calculated. Results show that among GLVs studied, the level of β-carotene (50–130 mg/100 g dry wt) was higher in nine GLVs than other carotenoids while lutein (50–187 mg/100 g dry wt) and zeaxanthin (1–5 mg/100 g dry wt) were higher in 12 GLVs than other xanthophylls. α-Carotene was detected only in nine GLVs, ranging from 1 to 37 mg/100 g dry wt. Interestingly, *Chenopodium album*, *Commelina benghalensis* and *Solanum nigrum* were found to contain higher levels of both lutein and β-carotene in the range of 84–187 and 50–115 mg/100 g dry wt, respectively. The values of retinol equivalents (RE) ranged from 641 to 19101 and were higher (>10,000) in six GLVs of the 30. The results demonstrate that GLVs studied contained higher levels of RE and lutein.

Keywords: Leafy vegetables; Carotenoids; Vitamin A activity; Chromatography

1. Introduction

Providing modern healthcare to rural people in India is still a far-reaching goal due to economic constraints (Grover, Yadav, & Vats, 2002). Hence, people mainly depend on the locally available plant materials to cure various health disorders (Chopra, Nayar, & Chopra, 1956; Grover & Vats, 2001). Plants possess components, which render beneficial properties (Tanabe, Yoshida, & Tomita, 2002). Hence, currently attention is being drawn towards exploring plant sources for substances that provide nutritional and pharmaceutical advantages to humans. Green leafy vegetables (GLVs) are a good source of minerals and vitamins. The ethno-botanical reports offer information on medicinal properties of GLVs like anti-diabetic (Kesari, Gupta, & Watal, 2005), anti-histaminic (Yamamura, Ozawa, Ohtani, Kasai, & Yamasaki, 1998), anti-carcinogenic (Rajesh Kumar et al., 2002), hypolipidemic (Khanna, Rizvi, & Chander, 2002), and anti-bacterial activity (Kubo, Fijita, Kubo, Nehei, & Gura, 2004). In most studies, crude extracts of GLVs were used to demonstrate their health beneficial potency. Sultana, Perwaiz, Iqbal, and Athar (1995) studied the hepatoprotective effect of *Solanum nigrum* and *Cichorium intybus* extracts in vitro. Kesari et al. (2005) and Jayaram et al. (1997) reported the hypoglycemic effect of *Murraya koenigii* and anti-viral properties of *Phyllanthus niruri*. Except few studies (Nambiar & Seshadri, 1998; Rajyalakshmi et al., 2001; Singh, Kawatra, & Sehgal, 2001), data on the carotenoid composition of medicinally important Indian GLVs is limited.

GLVs are rich sources of carotenoids (Devadas & Saroja, 1980). It has been reported that available β-carotene from greens in India is 95%, and out of this 90% is contributed by GLVs (Singh et al., 2001). An increased intake of

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0308-8146/$ - see front matter © 2006 Published by Elsevier Ltd.
doi:10.1016/j.foodchem.2006.04.015

β-carotene rich food in the daily diet may be one of the strategies for improving vitamin A status among children instead of synthetic vitamin A (Gopalan, 1992). India, having a variety of natural climates and seasons, has a number of nutritionally and medicinally important plant species such as spinach, coriander, amaranth, curry leaf, and mint, which are relatively inexpensive and readily available throughout the year. Although GLVs used in this study are medicinally important, these are less commonly used for nutritional purpose, which is due to lack of awareness on their nutritional importance.

Vitamin A deficiency (VAD) and age related macular degeneration (AMD) are accepted as serious public health problems among children and adults in India. It is reported that 25% of the 15 million blind in the world are from India (Baskarachary, 1996). It is known that VAD and AMD are primarily due to inadequacy of provitamin A and macular pigments in the diet. To encourage the concerned, data on these pigments in GLVs grown in different geographical regions is very much essential because their composition varies markedly with change in climatic conditions. Chen and Chen (1992) reported 100 ± 8 μg of β-carotene and 78 ± 7 μg of lutein per gram of wet weight in *Ipomoea aquatica*. While, Wills and Rangga (1996) have reported much lower contents of these carotenoids in the same species. Data on carotenoid content of GLVs may provide information to consumers and public health workers to assess the dietary carotenoid intake and their relationship to health and disease. Although GLVs used in this study have beneficial effects against various health disorders in India (Table 1), their carotenoid composition is not studied well. Hence, the present study was aimed at screening their carotenoid composition. The outcome of the present study may help in identifying GLVs rich in specific carotenoids for supplementation purposes. Chemical structures of major carotenoids found in GLVs are shown in Fig. 1 (Kimura & Rodriguez-Amaya, 2003).

2. Materials and methods

2.1. Samples

Freshly harvested GLVs, in duplicate, were obtained from two different local farms on the day of analysis during

Table 1
Botanical, family, common, local names and medicinal properties of leafy vegetables screened for carotenoid composition

Botanical name	Family	Common name	Local name	Medical application[a]
Allium cepa L.	Liliaceae	Onion stalks	Erulli	Anti-parasitic
Allmania nodiflora (L.) R.Br.	Amaranthaceae	Celosia	Gorji soppu	Used in snake bite
Alternanthera pungens Kunth	Amaranthaceae	Khaki weed	Mirja mullu	Diuretic
Alternanthera sessilis (L.) Dc.	Amaranthaceae	Joy weed	Honagone soppu	Hepatoprotective
Amaranthus gangeticus L.	Amaranthaceae	Amaranth	Dantu soppu	Anti-oxidant
Amaranthus tristis L.	Amaranthaceae	Arai keerai	Arai keerai	Diuretic
Amaranthus viridis L.	Amaranthaceae	Slender amaranth	Kil keerai soppu	Anti-oxidant
Basella alba L.	Bassellaceae	Indian spinach	Basale soppu	Anti-mutagenic[b]
Beta vulgaris L.	Chenopodiaceae	Beat greens	Beet	Laxative and diuretic
Boerhavia diffusa L.	Nyctaginaceae	Hog weed	Punarnava	Anti-diabetic[c]
Brassica oleracea L. var. *botrytis* L.	Brassicaceae	Broccoli	Hukosina yele	Anti-cancer[d]
Chenopodium album L.	Chenopodiaceae	Lamb's quarters	Sakothina soppu	Anti-helminthic
Commelina benghalensis L.	Commelinaceae	Jio	Kanuraka soppu	Anti-leprocy
Coriandrum sativum L.	Apiaceae	Coriander leaves	Kothambari soppu	Anti-bacterial[e]
Cucurbita maxima Duchesne	Cucurbitaceae	Winter squash	Kumbala soppu	Anti-helminthic
Daucus carota L.	Apiaceae	Carrot greens	Gajri soppu	Purgative
Gynandropsis pentaphylla L.	Capparidaceae	Spider wisp	Narimbele soppu	Anti-helminthic
Hibiscus cannabinus L.	Malvaceae	Kenaf	Pundi soppu	Aphrodisiac
Hydrocotyle asiatica L.	Apiaceae	Indian pennywort	Ondelaga	Anti-ulcer[f]
Lactuca sativa L.	Asteraceae	Indian lettuce	Lettuce soppu	Anti-oxidant
Mentha spicata L.	Lamiaceae	Spear mint	Pudina soppu	Hysteria
Murraya koenigii L.	Rutaceae	Curry leaf tree	Karibevu	Renal pain
Phyllanthus niruri L.	Euphorbiaceae	Chanca piedre	Kiru nelli	Jaundice
Piper betle L.	Piperaceae	Betel leaf	Veelyadele	Wound healing
Portulaca oleracea L.	Portulacaceae	Purslane	Doddagoni soppu	Anti-scorbutic
Rumex acetosella L.	Polygonaceae	Sheep sorrel	Sukki soppu	Renal problems
Solanum nigrum L.	Solanaceae	Black night shade	Ganika soppu	Cirrhosis of liver
Talinum cuniefolium Willd.	Portulacaceae	Ceylon spinach	Ceylon basale	Aphrodisiac
Trianthema portulacastrum L.	Aizoaceae	Desert horse purslane	Masoppu	Anti-rheumatic, diuretic
Tribulus terrestris L.	Zygophyllaceae	Puncture vine	Neggalu	Stomachic

[a] Useful plants of India (CSIR, 1986), otherwise mentioned.
[b] Yen et al. (2001).
[c] Pari and Satheesh (2004).
[d] Reddy et al. (1999).
[e] Kubo et al. (2004).
[f] Cheng et al. (2004).

morning (24–26 °C). The botanical, family, common, local names, and medicinal importance of the GLVs studied are given in Table 1. The leafy portions without stems were separated and used for the extraction of carotenoids. To obtain a homogeneous sample, a known amount (50 g) of each leafy vegetable was washed with deionized water, drained and ground for 5 min in a blender and processed immediately.

2.2. Chemicals

Standard all-*trans* β-carotene (98%), α-carotene (carotene mixed isomers from carrot, 1:2, 95%), lutein (99%), DL-α-tocopherol, and chlorophylls *a* and *b* were purchased from Sigma-Aldrich (St. Louis, MO, USA). Neoxanthin (95%), violaxanthin (98%) and zeaxanthin (98%) were kindly donated by Dr. Akhihiko Nagao (National Food Research Institute, Tsukuba, Japan). HPLC grade methanol, acetonitrile, dichloromethane, hexane and ammonium acetate were purchased from S.D Fine Chemicals (Mumbai, India).

2.3. Extraction of carotenoids

Carotenoids were extracted according to the procedure described by Lakshminarayana, Raju, Krishnakantha, and Baskaran (2005). In brief, carotenoids were extracted with ice-cold acetone until the samples became colourless (final volume, 400 mL). The crude extract (50 mL) was taken in a separatory funnel; 100 mL of petroleum ether and 100 mL of aqueous sodium chloride (25%, w/v) were added, after mixing well, the upper layer was separated. The extraction was repeated three times (total volume: 250 mL). The extract was dried over anhydrous sodium sulphate (20 g) and filtered through Whatmann No.1 filter paper. The filtrate was evaporated to dryness in a rotary evaporator (Buchi, Flawil, Switzerland) at 30–35 °C and redissolved in a known volume of hexane and an aliquot

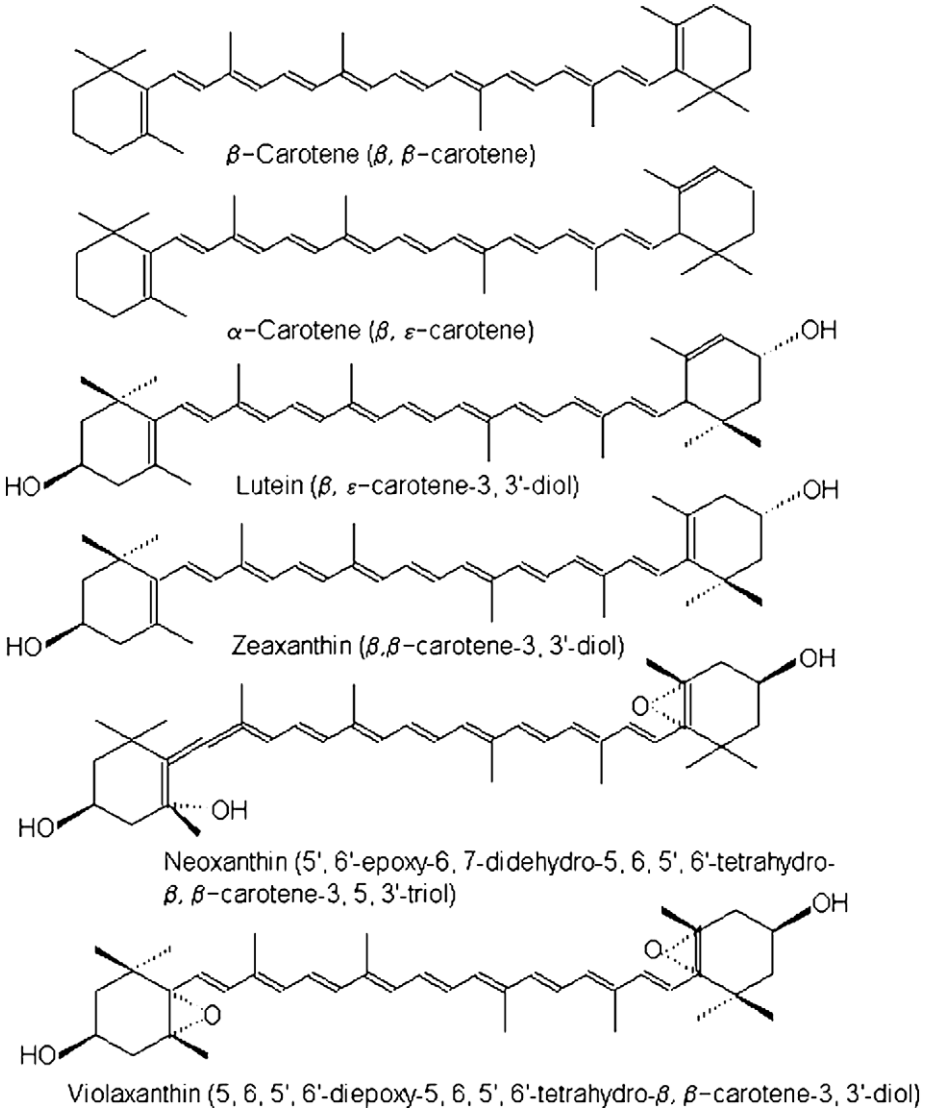

Fig. 1. Chemical structures of major carotenoids present in leafy vegetables.

(100 μL) was used for HPLC analysis. Sample handling, homogenization and extraction were carried out at 4 °C, under dim yellow light to minimize photo-isomerization and oxidation of carotenoids.

2.4. HPLC analysis

The carotenoid content of GLVs was analysed as described by Lakshminarayana et al. (2005). In brief, the carotenoids were separated on a SGE C-18 (ODS) column, 25 cm × 4.6 mm i.d., 5 μm, 120A0 (SGE Co., Mumbai, India). Acetonitrile/methanol/dichloromethane (60:20:20, v/v/v) containing 0.1% ammonium acetate was used as a mobile phase for the separation of carotenoids. Samples were injected (20 μL) for HPLC analysis under isocratic condition at a flow rate of 1 mL/min and were monitored at 450 nm with UV–Vis detector (Shimadzu, Kyoto, Japan). The peak identities of carotenoids were confirmed by their retention time of standard chromatograms recorded with a Shimadzu model LC-10Avp series equipped with SPD-10AVP detectors (Fig. 3A and B). Whereas, the λ_{max} values of these compounds were confirmed by their characteristic spectrum recorded with PDA detector. They were quantified from their peak areas in relation to respective reference standards.

2.5. Calculation of vitamin A activity

The vitamin A activity, as retinol equivalents (RE), was calculated based on the in vivo conversion factor proposed

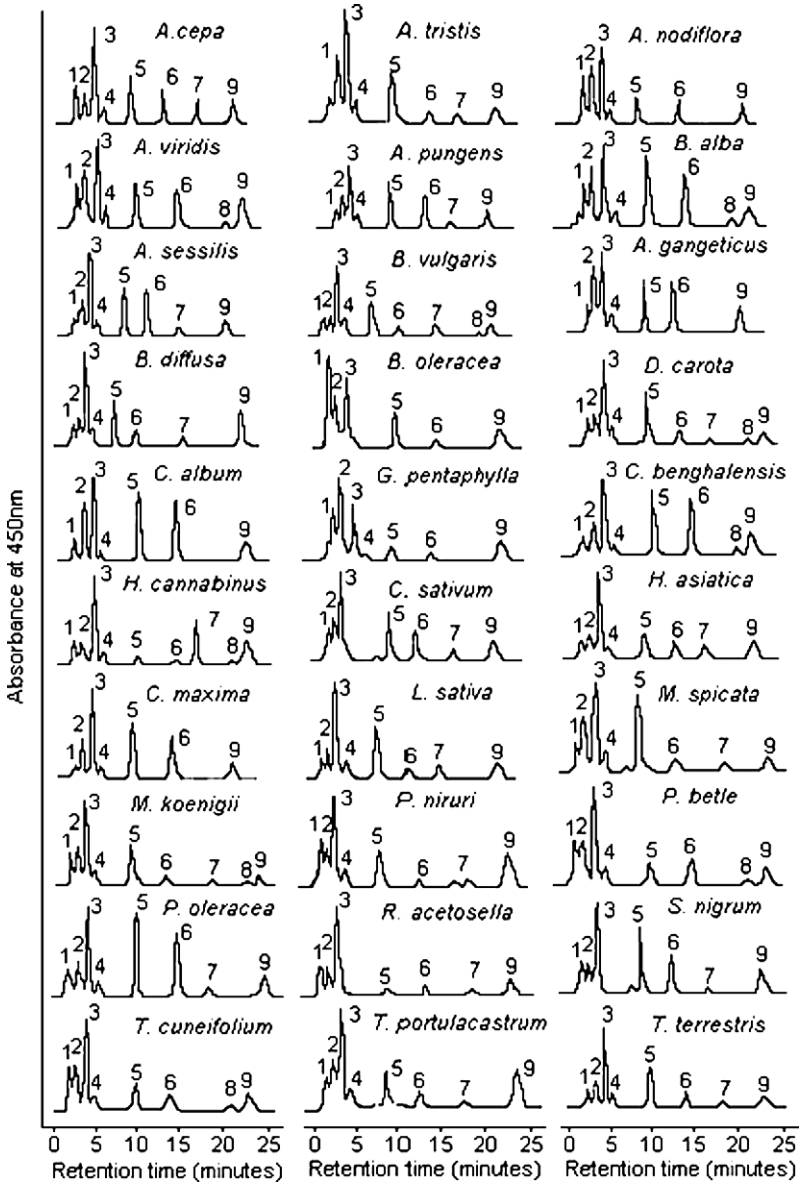

Fig. 2. HPLC profile of carotenoids in leafy vegetables. Peaks: 1, neoxanthin; 2, violaxanthin; 3, lutein; 4, zeaxanthin; 5, chlorophyll *b*; 6, chlorophyll *a*; 7, unidentified; 8, α-carotene and 9, β-carotene.

by WHO and NRC, where 1 RE corresponds to 6 μg of β-carotene and 12 μg of α-carotene (WHO, 1982; National Research Council, 1989, chap. 7).

3. Results and discussion

Major pigments in GLVs used in the present study consist of three classes of carotenoids in the order of chromatographic elution on C_{18} column and these are xanthophylls (oxygenated carotenoids), chlorophylls and hydrocarbon carotenoids that separated within 23 min (Fig. 2). The carotenoids were separated under isocratic condition in the order of neoxanthin (peak 1), violaxanthin (peak 2), lutein (peak 3), zeaxanthin (peak 4), chlorophylls *b* and *a* (peaks 5 and 6) and α- and β-carotenes (peaks 8 and 9), respectively. Whereas, Kimura and Rodriguez-Amaya (2003) isolated these carotenoids from lettuce by HPLC under gradient condition, which required 50 min to separate them. However, in this study the separation of carotenoids was achieved within 23 min under isocratic condition. The absorption maxima (λ_{max}) for xanthophylls and the hydrocarbon carotenoids (Table 2) separated from GLVs were comparable with respective standards and values reported in the literature (Emenhiser, Sander, & Schwartz, 1995).

Table 2
Reported and observed UV–Vis absorption maxima (λ_{max}) of carotenoids from leafy vegetables

Carotenoids	λ_{max} [a]	λ_{max} [b,c]
Neoxanthin	438.5	436
Violaxanthin	446.4	440
Lutein	445.7	446
Zeaxanthin	452.6	452[d]
α-Carotene	444.5	444[d]
β-Carotene	449.5	448

[a] λ_{max} obtained in the present study.
[b] λ_{max} reported.
[c] Chen and Chen (1992).
[d] Emenhiser et al. (1995).

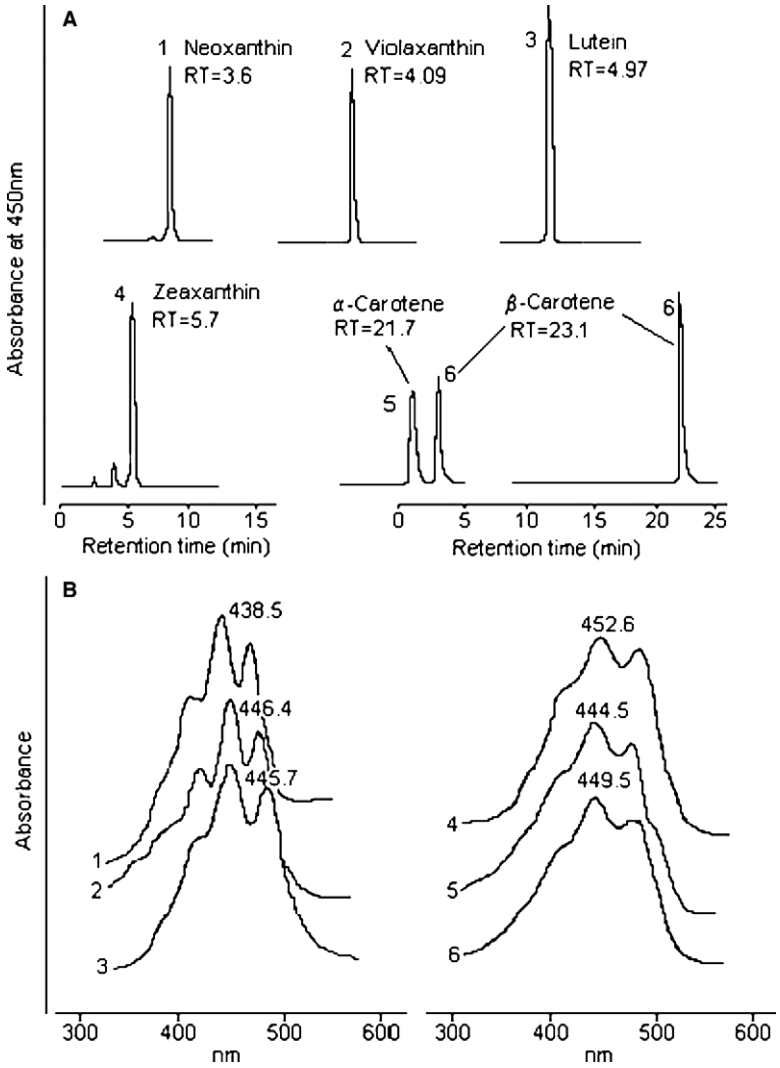

Fig. 3. HPLC profile of standard carotenoids (A) and their absorption spectra (B). 1, neoxanthin; 2, violaxanthin; 3, lutein; 4, zeaxanthin, 5; α-carotene and 6, β-carotene.

The HPLC profiles of carotenoids and their concentration in 30 GLVs studied are shown in Fig. 2 and Table 3. Though, the HPLC profile of all GLVs was found to be comparatively similar, the major difference appears to be their concentrations. For example, the chromatogram of *Amaranthus viridis* and *Chenopodium album* (Fig. 2) shows the presence of both hydrocarbon and xanthophyll carotenoids; however, their relative concentration was found to be different compared with other leafy vegetables studied (Table 3). Interestingly, the level (mg/100 g dry wt) of β-carotene and lutein in *A. viridis* (58.95, 90.43), *C. album* (114.61, 187.59), *Commelina benghalensis* (92.82, 181.3), *Coriandrum sativum* (67.5, 9.92), *P. niruri* (60.88, 77.55) and *S. nigrum* (50.11, 84.86) were higher than other GLVs. These differences may be related to species variations. Chen and Chen (1992) have reported that factors like species, part of the plant, degree of maturity at harvest, cultivation and post harvest handling practices influence on the carotenoid levels. Similarly, Tee and Lim (1991) also reported β-carotene in *C. sativum*, *Lactuca sativa*, *M. koenigii*, and *S. nigrum* at 3.16, 0.097, 9.32 and 7.04 mg/100 g edible portions, respectively; those were different from the values obtained in this study. Among the GLVs analysed in this study, nine were found to contain α-carotene ranging from 1 to 37 mg/100 g dry wt and its level was higher (21.53 mg/100 g dry wt) in *Daucus carota* compared with others (Table 3). β-Cryptoxanthin was not amenable for quantitation since it may be present at below the detectable limit (0.1 pmol). Among GLVs analysed, seven were found to contain relatively a higher level of β-carotene ranging from 50.11 to 114.6 mg/100 g dry wt, whereas in other GLVs its level was ranging from 3.85 to 43.82 mg/100 g dry wt. In case of lutein, 12 GLVs were found to contain higher level of lutein in the range of 50.84–187.6 mg/100 g dry wt and in others its level ranging from 4.5 to 42.65 mg/100 g dry wt (Table 3). The total carotenoid content of certain GLVs analysed in this study were different from the values reported by Rajyalakshmi et al. (2001). For example, they reported total carotenoids in *Alternanthera sessilis*, *Amaranthus gangeticus*, *A. viridis* and *Trianthema portulacastrum* as 24.02, 20.67, 26.45 and 17.61 mg%, respectively. Whereas, the present study reports the total carotenoids for the same species as 97.62, 78.99, 253.86 and 87.21 mg%, respectively. These differences may be related to climatic, geographic conditions and cultivars differences from where samples were collected for analysis. They have

Table 3
Carotenoid composition (mg/100 g dry weight) of selected leafy vegetables analysed by HPLC

Leafy vegetables	Xanthophylls				Total xanthophylls[a]	Provitamin A carotenoids		Total provitamin A carotenoids[b]
	Neoxanthin	Violaxanthin	Lutein	Zeaxanthin		α-Carotene	β-Carotene	
A. cepa	6.61	1.83	30.28	0.21	38.93	ND	16.90	16.90
A. gangeticus	1.46	26.50	32.02	0.34	60.32	ND	18.67	18.67
A. nodiflora	7.74	8.90	23.10	0.18	39.92	ND	9.63	9.63
A. pungens	ND	42.03	71.86	0.67	114.56	ND	34.66	34.66
A. sessilis	13.89	23.93	32.47	0.26	70.55	ND	27.07	27.07
A. tristis	1.15	19.15	30.30	0.23	50.83	ND	16.76	16.76
A. viridis	12.63	84.06	90.43	1.04	188.16	6.75	58.95	65.70
B. alba	7.74	6.27	113.82	1.76	129.59	18.23	43.82	62.05
B. diffusa	1.41	3.93	26.83	0.19	32.36	ND	27.67	27.67
B. oleracea var. *botrytis*	0.52	1.45	4.50	ND	6.47	ND	3.85	3.85
B. vulgaris	6.39	3.97	26.86	0.14	38.36	1.54	12.50	14.04
C. album	ND	142.59	187.59	5.00	335.18	ND	114.61	114.61
C. benghalensis	ND	102.93	181.30	2.06	286.29	37.17	92.82	129.99
C. maxima	ND	15.58	27.18	0.25	43.02	ND	10.27	10.27
C. sativum	5.47	83.43	9.92	ND	98.82	ND	67.50	67.50
D. carota	2.09	7.00	40.17	0.59	49.85	21.53	12.09	33.62
G. pentaphylla	49.31	ND	42.65	1.28	93.24	ND	37.04	37.04
H. asiatica	0.89	0.65	15.93	ND	17.47	ND	9.02	9.02
H. cannabinus	5.95	ND	33.97	0.14	40.06	ND	26.02	26.02
L. sativa	5.75	29.09	87.12	ND	121.96	ND	42.72	42.72
M. koenigii	4.39	6.68	27.20	0.16	38.43	2.87	8.95	11.82
M. spicata	2.11	5.62	17.74	0.26	25.73	ND	7.48	7.48
P. betle	0.82	0.89	36.43	0.47	38.62	18.42	13.35	31.77
P. niruri	33.60	3.67	77.55	1.63	116.45	ND	60.88	60.88
P. oleracea	0.73	11.47	50.84	0.94	63.98	ND	27.05	27.05
R. acetosella	7.70	1.45	144.30	ND	153.45	ND	70.83	70.83
S. nigrum	2.79	22.17	84.86	ND	109.82	ND	50.11	50.11
T. cuniefolium	7.95	10.51	89.79	1.22	109.47	18.77	42.44	61.21
T. portulacastrum	2.50	5.00	41.51	0.44	49.45	ND	37.76	37.76
T. terrestris	1.34	8.84	56.39	0.04	66.61	6.1	30.81	36.91

ND: Not detected, below the detectable limit (0.1 pmol). Values are mean of duplicate determinations.
[a] Sum of neoxanthin, violaxanthin, lutein and zeaxanthin.
[b] Sum of α- and β-carotene.

collected GLVs during July to October from tribal areas in southeast region, but we have collected during May to June from southwest region of India.

The percentage of lutein and β-carotene in total carotenoids and vitamin A activity (retinol equivalent, RE) of GLVs is presented in Table 4. This is the first report on the individual carotenoid composition and vitamin A activity of medicinally important GLVs. Rajyalakshmi et al. (2001) reported vitamin A activity (RE) of *Allmania nodiflora*, *A. gangeticus*, *A. viridis*, *C. benghalensis* and *T. portulacastrum* as 0.93, 1.23, 1.19, 0.53 and 1.07 mg%, respectively, while, in the present study the RE of these GLV was different (1.61, 3.11, 10.39, 18.57 and 6.29 mg%). Interestingly, results show that less commonly used GLVs, namely *A. viridis*, *C. album*, *C. benghalensis*, *Cucurbita maxima*, *C. sativum*, *P. niruri*, and *Rumex acetosella* are found to contain higher RE ranging from 10.15 to 19.10 mg%, when compared with those of commonly consumed GLVs. Hence, the nutritional importance of those GLVs rich in RE needs to be habituated among various communities to combat VAD and AMD and this could be made possible by dietary counseling.

The percent differences observed among neoxanthin, violaxanthin and lutein in GLVs in this study may be attributed to the biosynthetic transformations of allenic end group of neoxanthin (Bonnett et al., 1969; Burns, Fraser, & Bramley, 2003). This may be the reason for the higher level of total xanthophylls (ranging from 6.47 to 335.18 mg/100 g dry wt) observed in GLVs compared with those of total provitamin A carotenoids (ranging from 3.85 to 130 mg/100 g dry wt). This is in agreement with findings of Wills and Rangga (1996), who reported higher level of xanthophylls in *Allium tuberosum*, *Amaranthus tricolor* and *Brassica chinensis* than those of hydrocarbon carotenoids. In contrast, Tee and Lim (1991) reported that β-carotene level in *S. nigrum* is significantly higher (7.04 mg/100 g edible portion) than that of lutein (2.88 mg/100 g edible portion). Further, in general, the hydroxylation of the α-carotene is known to be responsible for the formation of 3-hydroxy cyclic carotenoids and epoxy carotenoids. The absence of α-carotene in most of the GLVs may therefore be related to its conversion to lutein (Tee & Lim, 1991). This may be a reason for the higher content of lutein observed in GLVs (Table 3). Study is in progress to identify unknown peak (peak 7) eluted after chlorophylls at 17 min in certain GLVs. We have not quantified chlorophylls in GLVs studied since our objective was to study carotenoid composition and vitamin A activity of β-carotene.

Table 4
Total carotenoids (TC), percent of lutein, β-carotene in TC and vitamin A activity (RE) of α- and β-carotene in green leafy vegetables

Leafy vegetables	Total carotenoids[a]	% Lutein in TC	% α-Carotene in TC	% β-Carotene in TC	RE[b,c]
A. cepa	55.83	54.26	–	30.27	2816
A. gangeticus	78.99	40.53	–	18.67	3111
A. nodiflora	49.55	46.61	–	19.43	1605
A. pungens	49.22	48.15	–	23.22	5776
A. sessilis	97.62	33.26	–	27.72	4511
A. tristis	67.59	44.82	–	24.79	2793
A. viridis	253.86	35.62	0.48	23.22	10,387
B. alba	191.64	59.39	9.51	22.86	8822
B. diffusa	60.03	44.69	–	46.09	4645
B. oleracea	10.32	43.60	–	37.30	641
B. vulgaris	52.40	51.25	2.93	23.85	2211
C. album	449.90	41.69	–	25.47	19,101
C. benghalensis	416.28	43.55	8.92	22.29	18,567
C. maxima	53.27	51.02	–	19.27	1712
C. sativum	166.32	5.96	–	40.58	11,250
D. carota	83.47	48.12	25.79	14.48	3809
G. pentaphylla	130.28	32.73	–	28.43	6173
H. asiatica	26.49	60.13	–	34.05	1503
H. cannabinus	66.08	51.40	–	39.37	4338
L. sativa	164.68	52.90	–	25.94	7120
M. koenigii	50.25	54.12	5.71	17.81	1730
M. spicata	33.21	53.41	–	22.52	1246
P. betle	70.39	51.75	26.16	18.96	3760
P. niruri	177.33	43.73	–	34.33	10,146
P. oleracea	91.03	55.84	–	29.71	4508
R. acetosella	224.28	64.33	–	31.58	11,805
S. nigrum	159.93	53.06	–	32.45	8351
T. cuniefolium	170.68	52.60	11.00	24.86	8637
T. portulacastrum	87.21	47.59	–	43.29	6293
T. terrestris	103.50	54.47	5.89	29.76	5643

Values are mean of duplicate analysis.
[a] Sum (mg/100 g dry wt) of total xanthophylls and total provitamin A carotenoids shown in Table 3
[b] 1 RE = 6 μg β-carotene and 12 μg α-carotene.
[c] RE of α- and β-carotene.

4. Conclusions

This study shows that the selected leafy vegetables with medicinal value, but less commonly used for nutritional purpose contain higher levels of lutein than β-carotene. Interestingly, less commonly consumed GLVs, namely *C. album*, *C. benghalensis* and *R. acetosella* are the richest source of lutein, β-carotene and RE. Hence, these GLVs could be exploited as a good source of vitamin A and lutein to overcome VAD and AMD. The data on the composition of carotenoids could be helpful to create nutritional awareness among various communities on the importance of these GLVs.

Acknowledgments

This work was supported in part by the United Nations University-Kirin Co, Ltd. Research grant (Tokyo, Japan). The authors thank Dr. V. Prakash, Director, CFTRI; Dr. S.G. Bhat, Head, Department of Biochemistry and Nutrition, CFTRI and Dr. A. Nagao, Head, Department of Lipid Laboratory, National Food Research Institute, Tsukuba, Japan for their encouragement and support. Mr. M. Raju and Mr. R. Lakshminarayana acknowledge the grant of Senior Research Fellowship by Council of Scientific and Industrial Research, New Delhi, India.

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