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Carotene content of some common and less familiar foods of plant origin

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A number of commonly consumed plant foods including green leafy vegetables, roots and tubers, other vegetables and fruits were analysed for their total carotenes spectrophotometrically and by separation of provitamin A carotenoids on HPLC. β-Carotene is the predominant carotenoid in all foods. Green leafy vegetables (GLV) were found to be the best source of provitamin A, and also yellow fruits such as mango and papaya. Carrot contains significant amounts of α-carotene while, in papaya, β-cryptoxanthin is the predominant carotenoid. Incorporation of these vegetables in the diets of the children would be the most effective approach to combat vitamin A deficiency. A few lesser-known GLV were also analysed. Among them, chennangiaku and botla benda appeared to be good sources of β-carotene. Organised cultivation of these vegetables and fruits would help in overcoming the problem of vitamin A deficiency.

INTRODUCTION

Vitamin A is an essential micronutrient required for vision and a variety of metabolic functions in the body. In developing countries more than 80% of the dietary vitamin A is supplied by carotenoids present in plant foods. The most predominant and active carotenoid in these foods is β-carotene. The traditional method of carotenoid analysis involves adsorption chromatography followed by colorimetry or spectrophotometry (AOAC, 1980). The values given in food composition tables are often expressed as total carotenes estimated by colorimetry. Open-column chromatography used for separating different carotenoids, is time-consuming and suffers from incomplete resolution. Differences in vitamin A activities of carotenoids and inadequate specificity of the method of their separation may lead to an overestimation of vitamin A activity of the foodstuff. High-performance liquid chromatography (HPLC) is considered to be the most reliable, efficient and reproducible method for carotenoid analysis (Zakaria *et al.*, 1979, Beecher & Khachik, 1984). Recently, attempts have been made by Dixit *et al.* (1988) to analyse some of the Indian foods using this technique. However, the reported values pertain only to β-carotene. Using a different solvent system, Nelis and DeLeenheer (1983) could separate most vitamin A-active carotenoids. The present study was undertaken to analyse and document the carotene content of commonly consumed vegetables and fruits, using this technique. Apart from cultivated types, there are a number of wild growing greens which are edible, but there is no documented evidence of their provitamin A carotenoid content. Some of these less familiar leafy vegetables were also screened for their vitamin A activity.

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MATERIALS AND METHODS

Collection of food samples

The samples of commonly consumed foodstuffs including green leafy vegetables (17), roots and tubers (2), other vegetables (4) and fruits (8), were purchased in the local markets of the twin cities of Hyderabad and Secunderabad, on different occasions.

The lesser known or uncommon green leafy vegetables are neither cultivated nor marketed. They grow wild on waste lands and field bunds, generally during the rainy season. Samples of 21 such less familiar leafy vegetables were collected and analysed for their carotene content.

Replicate values of carotene content of vegetables were estimated and utilised in the analysis of data.

Extraction of carotenes

The procedure described by Zakaria *et al.* (1979) was used for extraction of carotene from food samples. The extract was stored under nitrogen at –20°C until analysis.

Spectrophotometry for total carotenes

Total carotene content of the extract was determined by measuring the absorbance in a spectrophotometer (Shimadzu) and using extinction coefficient $E^{1\%}$ 1 cm in petroleum ether (60—80°C): α-carotene 2710 at 445 nm, β-carotene 2500 at 450 nm, lycopene 3470 at 474 nm and β-cryptoxanthine 2386 at 452 nm.

HPLC separation of carotenes

HPLC analysis of β-carotene was carried out by the procedure described by Nelis and DeLeenheer (1983). The chromatographic system consisted of a Shimadzu model LC6A equipped with system controller, SCL 6A, a variable wave length detector, SPD-6AV, an integrator C-R3A chomatopack and a stainless-steel 25 cm × 4·6 mm separation column (Zorbax ODS18, 5 μm particles-Dupont). By injecting 20 μl of the sample extract on to the HPLC column, isocratic separation of carotenoids was accomplished with the mobile phase consisting of acetonitrile/dichloromethane/methanol in 70 : 20 : 10 (v/v) proportions, pumped at a flow rate of 2 ml/min. The effluent was monitored with the detector wavelength set at 450 nm and sensitivity 0·01 AUFS. External standards were all *trans* α-carotene, all *trans* β-carotene, and lycopene obtained from Sigma chemicals. γ-Carotene, zeaxanthine and β-cryptoxanthine were generous gifts from Hoffmann-La Roche (Switzerland). The HPLC was calibrated daily by injecting a full loop (20 μl of carotene standards, the concentration of each carotene ranging from 1 to 5 μg/ml of each carotene. The retention times observed were lutein 2·0 min, β-cryptoxanthine 5·1 min, lycopene 8·3 min, γ-carotene 12·8 min, α-carotene 13·5 min and β-carotene 14·6 min. Peak identification was based on retention

Table 1. Total and β-carotene content of common GLV (mean ± SD)[a]

Foodstuff — Local/botanical name	Number of samples analysed	Total carotene (mg/100 g)	β-Carotene	
			mg/100 g	% of total
(A) GLV with high vitamin A activity				
Drumstick (*Moringa oleifera*)	10	42·1b ± 8·8	19·7a ± 5·55	46·3c ± 7·97
Agathi (*Sesbania grandiflora*)	14	45·2a ± 5·54	15·4a ± 6·87	32·5e ± 11·5
Methi (*Trigonella foenum graecum*)	6	11·8fgi ± 3·70	9·2b ± 1·48	81·0a ± 10·71
Amaranth (*Amaranthus gangeticus*)	34	21·2cd ± 5·49	8·6b ± 2·78	39·7d ± 3·76
Curry leaf (*Murraya koenigii*)	8	21·4c ± 3·44	7·1bc ± 2·36	31·4e ± 5·99
Gogu (*Hibiscus sabdariffa*)	10	15·8e ± 3·58	5·8cd ± 2·77	34·5de ± 11·1
Pudina (mint) (*Menta arvensis*)	16	19·1de ± 5·0	4·3de ± 2·0	21·0g ± 5·44
Chammakura (*Colocasia antiquoram*)	10	19·1cde ± 4·24	5·5c ± 1·86	28·9e ± 6·82
Koyyalakura (*Sueda monoica*)	6	17·1de ± 0·70	4·8cd ± 0·63	28·1ef ± 2·76
Onion leaf (*Allium cepa*)	6	9·8gi ± 0·39	4·9cd ± 0·15	49·7b ± 1·54
Coriander (*Coriandrum sativum*)	6	15·2ef ± 1·30	4·8cd ± 0·16	31·6g ± 1·14
(B) GLV with moderate vitamin A activity				
Ceylon bacchali (*Talinum triangulare*)	6	10·6gi ± 2·13	3·0def ± 0·63	28·6e ± 2·34
Palak (*Spinacia oleracea*)	16	9·8gi ± 1·47	3·2def ± 1·24	31·8e ± 8·20
Bacchali (*Basella rubra*)	30	8·8gi ± 1·66	2·7f ± 0·74	30·2e ± 3·62
Chukka (*Rumex vesicarius*)	6	8·9gi ± 0·34	2·6f ± 0·34	29·3e ± 2·89
Radish (*Raphanus sativus*)	6	12·7efg ± 0·70	2·3f ± 0·49	17·9g ± 3·63
Lettuce (*Lactuca sativa*)	6	7·8i ± 0·44	1·4g ± 0·28	18·8g ± 3·04
'*F*' ratio (*d,f*)		77·9 (16,178)	39·6 (16,178)	39·5 (16,178)
Level of significance		***	***	***

[a]Variation in following letters between foodstuffs indicates significance of difference at 5% level ($P < 0.05$).
*** $P < 0.001$.

times and comparison with standards and co-chromatography. The recovery of added β-carotene through the saponification step was 95–102%. All results of carotene content were expressed as mg/100 g of fresh weight of food sample.

Statistical procedure

The mean and standard deviation for each foodstuff was calculated. The differences in mean values between foodstuffs were tested using one way ANOVA and multiple comparison '*t*'-test procedure. Appropriate log transformations were utilised wherever necessary for the flexible use of ANOVA.

Multiple comparison limits were fixed at the 5% level of significance with the use of Student's '*t*'-table values.

RESULTS AND DISCUSSION

Common green leafy vegetables

There was a wide variation in total carotene content of green leafy vegetables (GLV), the values ranging from 7 mg in lettuce to 45 mg in agathi, P < 0·001) (Table 1). An equally significant variation was observed for β-carotene (P < 0·001) (1·4 mg for lettuce to 19·7 mg for drumstick). β-Carotene was the only provitamin A carotenoid detected in these vegetables. Drumstick leaves were found to be the richest source of β-carotene (19·7 mg) followed by agathi (15·4 mg). However, the difference was not statistically significant. Both these plants are perennial, providing the leaf throughout the year. Amaranth, curry leaf, fenugreek and gogu are also good sources of β-carotene (7–9 mg), while palak, bacchali and other GLV contain relatively less. In most of these vegetables, only 30–50% of the total carotene was β-carotene while in fenugreek leaves it was around 80%.

Less familiar green leafy vegetables

These leafy vegetables also showed a variation in total and β-carotene content (P < 0·001) (Table 2). Seven out of 21 varieties analysed were found to be rich in β-carotene with values ranging from 7·0 to 12·5 mg. These include *Amaranthus spinosus*, botla benda, chirrakura and harichandan kura. On the other hand, a

Table 2. Total and β-carotene content of some less familiar green leafy vegetables (mean ± SD)[a]

Foodstuff—Local/botanical name	Number of samples analysed	Total carotene (mg/100 g)	β-Carotene mg/100 g	β-Carotene % of total
Botla benda (*Abutilon indicum*)	6	33·8c ± 1·94	12·6a ± 1·47	37·1bc ± 2·65
Chennangiaku (*Cassia* sp.)	10	48·4a ± 2·4	11·9a ± 2·17	24·4d ± 3·37
Yerramolakakaura (*Amaranthus* sp.)	8	47·9a ± 2·47	11·9a ± 1·48	24·9d ± 1·97
Mulla thotakura (*Amaranthus spinosus*)	8	35·9bc ± 2·98	10·9a ± 1·25	30·3c ± 2·18
Tulasi (*Ocimum sanctum*)	10	33·8c ± 2·36	8·15b ± 1·06	24·1d ± 2·01
Chirrakura	6	18·1gh ± 1·76	7·1bc ± 1·06	39·1ab ± 3·28
Harichandamkura	6	16·4gh ± 2·75	7·5b ± 1·43	45·4a ± 5·02
Betal leaf (*Piper beetle*)	8	18·7fgh ± 1·79	5·9cd ± 1·0	31·4c ± 3·58
Ponnagantikura (*Alternanthera sessilis*)	10	24·5e ± 3·35	5·7d ± 1·58	22·9d ± 3·89
Tummikura (*Leucas aspera*)	8	18·3gh ± 2·3	4·1e ± 0·89	22·1d ± 2·88
Uttareni (*Achyranthes aspera*)	6	26·7e ± 1·99	4·3e ± 0·73	15·9e ± 1·93
Chitramulam (*Plumbago zeylanica*)	6	30·2d ± 1·93	3·9e ± 1·06	12·9f ± 2·7
Golimittikura	6	19·3fg ± 1·33	1·9g ± 0·64	9·85h ± 2·8
Mullangantikura	6	30·7d ± 1·87	2·2fg ± 0·71	7·18i ± 2·13
Panpandlikura	6	36·5b ± 1·28	1·4h ± 0·31	3·92j ± 0·77
Ganijeraku	6	4·67j ± 1·49	1·1hi ± 0·1	0·77cd ± 8·01
Duggalikura (*Amaranthus uridis*	8	12·6i ± 1·81	1·1tij ± 0·36	8·41hi ± 2·08
Dusuduteega (*Cocculus hirsutus*)	6	20·8f ± 2·68	0·83jk ± 0·68	4·0j ± 0·68
Bunkuntikura	6	25·3e ± 1·93	2·5f ± 0·52	9·9gh ± 1·59
Gunagukura (*Celosia argentea*)	6	16·2h ± 1·75	1·2hi ± 0·19	7·6i ± 0·94
Tellagarjelikura	6	5·98j ± 1·98	0·68k ± 0·12	12·5fg ± 4·6
'*F*' ratio (*d,f*)		209·3 (20,127)	139·8 (20,127)	102·7 (20, 127)
Level of significance		***	***	***

[a]Variation in following letters between foodstuffs indicates significance of difference at 5% level (P < 0·05).
*** P < 0·001.

Table 3. Total and β-carotene content of tubers and other vegetables (mean ± SD)[a]

Foodstuff—Local/botanical name	Number of samples analysed	Total carotene (mg/100 g)	β-Carotene	
			mg/100 g	% of total
Tubers				
Carrot[b] (*Daucus carota*)	12	8·85a ± 2·0	6·5a ± 1·46	69·7b ± 6·96
Sweet potato (*Ipomea batatas*)	6	2·23b ± 0·23	1·87b ± 0·14	84·1a ± 5·07
Other vegetables				
Pumpkin (*Cucurbita minima*)	10	2·06bc ± 0·77	1·16c ± 0·57	55·1c ± 8·19
Chillies green (*Capsicum annum*)	8	2·44bc ± 0·46	1·13c ± 0·8	49·6c ± 8·28
Tomato ripe (*Lycopersicon esculentum*)	10	3·0c ± 0·87	0·62d ± 0·19	20·8d ± 3·39
Capsicum (bell pepper) (*Capsicum* sp.)	6	0·69d ± 0·24	0·11e ± 0·04	15·8e ± 3·39
'*F*' ratio (*d,f*)		68·5 (5,46)	154·1 (5·46)	169·6 (5·46)
Level of significance		***	***	***

[a]Variation in following letters between foodstuffs indicates significance of difference at 5% level ($P < 0{\cdot}05$)·
[b]Also contains α-carotene: 1·76 mg/100 g.
*** $P < 0{\cdot}001$.

few like mullangantikura and chitramulam, though high in total carotene, had a low β-carotene content. Many of these less familiar leafy vegetables would be comparable with the cultivated species of GLV and can be exploited further to enlarge the list of commonly consumed provitamin A-rich vegetables.

Most of these species have been botanically identified. They are distributed mostly in the tropics, subtropics and warm temperate regions of the world. *Leucas aspera* is also present in the West Indies, South Africa, Arabia, southern China and Indo-Malaya regions; *Achyranthus aspera* in the sub-tropics of Africa, and Perth in Australia (Willis & Shaw, 1982).

Tubers and other vegetables

Carotene content of these vegetables is presented in Table 3. In carrot, over 70% of the total carotene was β-carotene and the rest was α-carotene. The traditional varieties of sweet potatoes are white fleshed and contain no carotenes. Analysis of the new variety — 'kiran' (yellow fleshed), however, showed significant amounts of β-carotene (1·8 mg). Green chillies and pumpkin also contain appreciable amounts of β-carotene (1 mg). Tomatoes contain lycopene, a powerful singlet oxygen quencher, as the major carotene and its β-carotene content is only 0·59 mg.

Table 4. Total and β-carotene content of common fruits (mean ± SD)[a]

Foodstuff—Local/botanical name	Number of samples analysed	Total carotene (mg/100 g)	β-Carotene	
			mg/100 g	% of total
Dates, Indian (*Phoenix* sp.)	6	3·68a ± 0·23	2·95a ± 0·34	79·9a ± 5·6
Mango (*Mangifera indica*)	12	2·21ab ± 1·15	1·71b ± 0·95	76·9a ± 7·55
Papaya[b] (*Carica papaya*)	10	2·76b ± 0·94	1·05b ± 0·44	36·7b ± 5·14
Orange (*Citrus aurantium*)	6	2·25b ± 0·48	0·17c ± 0·08	7·2d ± 2·0
Cherry (*Prunus* sp.)	6	0·49c ± 0·16	0·14c ± 0·06	27·6c ± 7·76
Jack fruit (*Artocarpus integrifolia*)	6	0·51c ± 0·07	0·16c ± 0·06	30·8bc ± 8·04
Jambu (*Syzygium cuminii*)	8	0·08d ± 0·04	0·06d ± 0·03	69·9b ± 14·28
Guava (*Psidium guajava*)	6	0·05d ± 0·02	0·001c ± 0·0001	3·1e ± 1·17
'*F*' ratio (*d,f*)		8·83 (7·52)	131·05 (7·52)	204·2 (7·52)
Level of significance		***	***	***

[a]Variation in following letters between foodstuffs indicates significance of difference at 5% level ($P < 0{\cdot}05$)·
[b]Also contains α-carotene: 1·04 mg/100 g.
*** $P < 0{\cdot}001$.

Fruits

Among the fruits analysed (Table 4), mango and Indian dates were relatively high in β-carotene content. In papaya β-carotene is only 1·0 mg, but it contains a significant amount of β-cryptoxanthine (1·04) which has 50–60% of the potency of β-carotene (Baunfeind, 1972). This enhances the vitamin A value of papaya.

Thus these studies show that a number of green leafy vegetables including some less familiar types are rich sources of β-carotene. If GLV with relatively high carotene levels like amaranth and colocasia are used, a daily consumption of 30 g is sufficient to meet the requirements of an adult. Since drumstick and agathi leaves contain highest amounts of β-carotene, the daily requirement will be much less (10–15 g for an adult). Half the amount is sufficient to meet the requirements of a preschool child. Incorporation of these vegetables into the diets of children would be the most effective approach to combat vitamin A deficiency. These studies have also identified certain less familiar edible plant sources rich in β-carotene. A systematic study of their agronomic feasibility for general cultivation would help to augment the food resources of vitamin A.

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