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Carotene content of some common (cereals, pulses, vegetables, spices and condiments) and unconventional sources of plant origin

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Abstract

This study provides new data on the the total carotenoids and β-carotene content of commonly consumed cereals, pulses, vegetables, spices and condiments. Separation of carotenoids by HPLC showed that β-carotene is the predominant carotenoid in all the foods studied. Cereals and pulses appear to be poor sources of provitamin A precursors. Among the vegetables studied pumpkin, ridge gourd, green chillies, tomato, green peas, field beans and French beans are not only inexpensive but are better sources of β-carotene (20–120 mg/100 g). Among the spices and condiments, red chilli (1310 mg/100 g) and Smilax (2136 mg/100 g), which are regularly used in Indian recipes are good sources of provitamin A precursors. The study also identified unconventional sources like *Gulmohar, Peltiforum ferruginum,Lucern* and *Spirulina* as rich sources of β-carotene. Considering that Indian diets predominantly consist of cereals and pulses, choosing appropriate combinations of cereals and pulses will contribute significantly to overall vitamin A intakes. Together with our earlier efforts, the present study has generated a database of β-carotene contents of Indian plant foods, which could be of help in the elimination of vitamin A deficiency.

Keywords: Cereals; Pulses; Vegetables; Spices and condiments; Unconventional sources; β-carotene; HPLC

1. Introduction

Vitamin A deficiency (VAD) remains widespread in many countries of south-east Asia and global efforts are aimed at the virtual elimination of VAD and all of its consequences. As a short-term measure, periodic administration of large doses of vitamin A has been implemented to reduce the serious consequences of VAD (Vijayaraghavan, Rameswara Sarma, Pralhad Rao, & Reddy, 1984). Since inadequate dietary intake of vitamin A is the primary cause of VAD, the most rational approach for its prevention would be to encourage the daily consumption of adequate amounts of foods rich in vitamin A.

In addition, many investigators have studied the relation between dietary carotenoid intake and health. Ong and Chytil (1983) showed the existence of an inverse relationship between cancer and dietary intake of β-carotene, while anti-ulcer properties of β-carotene and β-cryptoxanthin were reported by Moszik et al. (1983), and antiageing effects of carotenoids were demonstrated by Cutler (1984). Our earlier studies identified some rich sources of β-carotene among the commonly consumed green leafy vegetables, as well as some less familiar foods (Bhaskarachary, Rao, Deosthale, & Reddy, 1995). Our national database for the β-carotene content of foods has yet to shift from total carotenoids to β-carotene (Gopalan,

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Ramasastri, & Balasubramanian, 2000). In this paper, we have measured the β-carotene content in cereals, pulses, vegetables, spices and condiments, in addition to unconventional food sources of plant origin.

2. Materials and methods

2.1. Collection of samples

Samples of commonly consumed foods, including vegetables (22), cereals (6), pulses (6), spices and condiments (14), and unconventional foods (4) were collected from the local markets of the twin cities of Hyderabad and Secunderabad, Andhra Pradesh on different occasions.

Replicate values of carotene content of these food samples were determined. Extraction of total carotenoids and reversed phase HPLC separation of carotenes were performed according to the methods of Zakaria, Simpson, Brown, and Krstulovic (1979) and Nelis and De Leenher (1983), as described earlier (Bhaskarachary et al., 1995).

2.2. Spectrophotometry of total carotenoids

The procedure described by Zakaria et al. (1979) was used for extraction of carotenoids from food samples. The extract was stored under nitrogen at −20 °C until analysis. Total carotenoids content of the extract was determined by measuring its absorbance on a spectrophotometer and using extinction coefficients $[E^{1\%}_{1\mathrm{cm}}]$ in petroleum ether (60–80 °C), i.e. α-carotene: 2710 at 445 nm; β-carotene: 2500 at 450 nm; γ-carotene: 2720 at 461 nm and β-cryptoxanthin: 2386 at 452 nm.

2.3. HPLC separation of carotenes

HPLC analysis of β-carotene was carried out by the procedure described by Nelis and De Leenher (1983). The chromatographic system consisted of a Shimadzu (model LC6A) chromatograph equipped with system controller, SCL6A, a variable wave length detector, SPD-6AV, an integrator C-R3A chromato-pack and a stainless steel 250 × 4.6 mm column (Zorbax, ODS, 5 μm particle, Dupont). By injecting 20 μl of the sample extract on to the HPLC column, isocratic separation of carotenoids was accomplished, with a mobile phase consisting of acetonitrile: dichloromethane: methanol (70:20:10 (v/v)), at a flow rate of 1 ml per min. The effluent was monitored at 450 nm. External standard β-carotene and internal standard, β-apo-8-carotenal (trans) were purchased from Fluka Chemicals (USA). α-Carotene, γ-carotene and β-cryptoxanthin were purchased from Carotenature (Basel). The HPLC was calibrated daily by injecting (20 μl) of carotene standards, the concentration of each carotene ranging from 1 to 5 μg/ml of each carotene. Peak identification was based on retention times (α-carotene at 24 min, β-carotene at 25 min, methyl-β-apo-8-carotenate at 7 min) and confirmed using standards. The recovery of added carotenes and internal standard after the saponification step was 95–102%. All carotene values are expressed as μg/100 g of food samples.

Moisture was determined in all the food samples according to the method described in AOAC (1995).

2.4. Statistical procedure

The mean and standard deviation for each foodstuff was calculated. The differences in mean values between foodstuffs were tested using one-way analysis of variance.

3. Results and discussion

3.1. Cereals and pulses

Cereals like rice (*Oryza sativa*), wheat (*Triticum aestivum*) and the millets, maize (*Zea mays*), ragi (*Eleucine coracana*) and sorghum Jowar (*Sorghum vulgare*) showed wide variation in their total carotenoid content, as well as β-carotene (Table 1). The values of total carotenes ranged

Table 1
Total carotenoids and β-carotene content of commonly consumed cereals and pulses

Foodstuff	Moisture[a] (g/100 g)	Total carotenoids (μg/100 g)	β-carotene (μg/100 g)	% β-carotene of total carotenoids
Bajra (pearl millet; *Pennisetum typhoideum*)	12.5	179 ± 9.91	25 ± 3.85	13.8 ± 1.92
Jowar (sorghum; *Sorghum vulgare*)	11.9	71 ± 9.864	7 ± 1.58	9.2 ± 1.10
Maize (*Zea mays*)	14.9	1782 ± 68.1	171 ± 15.0	9.2 ± 0.837
Ragi (finger millet; *Eleusine coracana*)	13.2	53 ± 6.46	3 ± 1.14	6.4 ± 1.52
Wheat (*Triticum aestivum*)	12.8	46 ± 5.45	2 ± 0.84	3.6 ± 1.52
Rice (*Oryza sativa*)	13.7	0	0	0
Bengal gram (*Cicer arietinum*)	9.9	1760 ± 63.8	157 ± 12.8	8.8 ± 0.837
Black gram (*Phaseolus mungo*)	10.9	164 ± 10.3	5 ± 1.58	3.0 ± 1.23
Green gram (*Phaseolus aureus*)	10.1	376 ± 13.5	128 ± 7.65	33.8 ± 2.59
Lentil (*Lens esculenta*)	12.5	580 ± 13.8	2 ± 1.14	0.42 ± 0.196
Red gram (*Cajanus cajan*)	13.4	1190 ± 83.1	124 ± 12.5	10.6 ± 1.67
Soya bean (*Glycine max*)	8.2	46 ± 7.38	1 ± 0.447	2.0 ± 0.707

Values are mean ± SD (μg/100 g) of five determinations.
[a] Moisture content (g/100 g) of foodstuff (mean of five determinations).

Table 2
Total carotenoids and β-carotene content of commonly consumed vegetables

Foodstuff (local/binomial name)	Moisture[a] (g/100 g)	Total carotenoids (μg/100 g)	β-Carotene (μg/100 g)	% β-Carotene of total carotenoids
Purslane (*Portulaca oleracia*)	85.7	554 ± 341	1700 ± 72.8	31 ± 1.14
Cucumber (*Cucumis sativus*)	96.4	48 ± 6.94	0	0
Okra (*Abelmoschus esculentus*)	89.6	277 ± 18.1	69 ± 9.20	25 ± 3.11
Bitter gourd (*Momordica charantia*)	92.3	967 ± 26.0	84 ± 8.50	9 ± 0.84
Bottle gourd (*Lagenatia vulgaris*)	96.3	186 ± 9.86	50 ± 7.23	27 ± 4.66
Ridge gourd (*Luffa acutangula*)	95.3	991 ± 22.5	324 ± 9.81	33 ± 1.30
Snake gourd (*Trichosanthes anguina*)	94.5	171 ± 10.3	63 ± 7.33	37 ± 3.42
Little gourd *(Coccinia cordifolia)*	93.5	675 ± 38.8	142 ± 10.3	21 ± 1.73
Yellow pumpkin (*Cucurbita maxima*)	92.8	2120 ± 100	1180 ± 44.6	55 ± 3.78
Capsicum (*Capsicum annuum* var.)	92.4	719 ± 52.3	157 ± 12.6	22 ± 2.51
Green chillies (*Capsicum annuum*)	85.7	2410 ± 97.1	1020 ± 46.7	42 ± 3.27
Cabbage (*Brassica oleracea* var. *capitala*)	91.8	226 ± 21.6	26 ± 5.93	11 ± 2.17
Cauliflower (*Brassica oleracea* var. *botrytis*)	90.8	37 ± 8.82	2.0 ± 0.55	4.0 ± 1.14
French beans (*Phaseolus vulgaris*)	91.5	1260 ± 34.6	393 ± 23.6	31 ± 1.79
Field beans (*Dolichos lablab*)	86.2	1910 ± 87.7	554 ± 38.2	29 ± 0.71
Green beans (*Phaseolus coccineus*)	87.5	1650 ± 198	239 ± 18.5	15 ± 0.84
Tomato (*Lycopersicum esculentus*)	93.5	3090 ± 98.8	59.7 ± 11.5	19 ± 1.14
Chow chow (*Sechium edule*)	92.5	97 ± 11.5	2.0 ± 0.45	2.0 ± 0.71
Brinjal (*aubergine*; *Solanum melongena*)	92.8	323 ± 28.0	169 ± 8.49	52 ± 3.96

Values are mean ± SD (μg/100 g) of five determinations on fresh weight basis.
[a] Moisture content (g/100 g) of foodstuff (mean of five determinations).

from zero (rice) to 1780 μg (maize) and similar variation was observed in the β-carotene content. In general, cereals were poor sources of β-carotene. Even though the average daily intake of cereals and millets among Indian pre-school children is about 80% (217 g) of the recommended daily intake (RDI) of 270 g (NNMB, 2002) and the intake of cereals by the Indian population, in general, is more than 50%, a combination of cereals may not contribute sufficiently to the overall vitamin A intake, without the addition of other foods.

Total carotenoids and β-carotene varied significantly in pulses also (Table 1), from 46 μg (soy bean) to 1760 μg (Bengal gram); pulses are better sources of β-carotene (0–171 μg/100 g) than cereals. Red gram, the predominant pulse in the Indian diet is a rich source of β-carotene (124 μg/100 g).

3.2. Vegetables

Among the vegetables studied, yellow pumpkin (1180 μg/100 g), green chillies (1020 μg/100 g), *Portulaca oleracia* (1700 μg/100 g), field beans (554 μg/100 g) and French beans (393 μg/100 g) are rich sources of β-carotene. (Table 2). Though the β-carotene content of Thai vegetables (Speek, Speek-Saichua, & Schreurs, 1988) is similar to our data, differences in other vegetables could be due to geographical or varietal differences (Mercandate & Rodriguez-Amaya, 1991). Tomato contains relatively

Table 3
Total carotenoids and β-carotene content of spices and condiments

Foodstuff	Moisture[a] (g/100 g)	Total carotenoids (μg/100 g)	β-carotene (μg/100 g)	% β-Carotene of total carotenoids
Japathri (mace) (*Myristica fragrance*)	16.0	17900 ± 0.83	2170 ± 0.23	12.1 ± 0.81
Red chilli (*Capsicum annum*)	10.1	113000± 1.77	1310 ± 0.25	1.39 ± 0.57
Dalchini Chekka (*Cinnamomum zeylanicum*)	7.0	1740 ± 0.21	180 ± 0.02	10.4 ± 1.43
Pattaku (*Smilax* Sps)	7.4	13200 ± 1.06	2130 ± 0.21	16.3 ± 2.32
Miryalu (Pepper) (*Piper nigram*)	18.2	1620 ± 0.24	220 ± 0.04	13.3 ± 0.97
Somp (*Anisum sativum*)	8.1	5970 ± 0.76	1480 ± 0.06	25.1 ± 2.55
Omam (*Trigonella foenumgraecum*)	7.5	2040 ± 0.15	870 ± 0.10	42.7 ± 4.65
Fenugreek (*Trigonella foenumgraecum*)	13.6	780 ± 0.13	140 ± 0.03	18.1 ± 4.26
Turmeric (*Curcuma longa*)	13.2	510 ± 0.11	60 ± 0.02	13.5 ± 4.53
Shajeera (*Cerum carvi*)	11.9	1250 ± 0.27	190 ± 0.02	15.8 ± 3.52
Cumin seed (Jeera) (*Cuminum cyminium*)	11.6	600 ± 0.10	80 ± 0.01	12.9 ± 0.67
Lavang (Cloves) (*Eugenia caryophyllate*)	25.3	490 ± 0.09	70 ± 0.01	15.6 ± 3.31
Ginger (*Zingiber Officinalis*)	80.7	720 ± 0.06	90 ± 0.01	12.4 ± 2.68
Coriander (*Coriandrum sativum*)	11.4	1010 ± 0.12	160 ± 0.01	16.2 ± 2.54

Values are mean ± SD (μg/100 g) of five determinations.
[a] Moisture content (g/100 g) of foodstuff (mean of five determinations).

Table 4
Total carotenoids and β-carotene content of unconventional sources

Foodstuff	Moisture[a] (g/100 g)	Total carotenoids (μg/100 g)	β-Carotene (μg/100 g)	% β-Carotene in total carotenoids
Gulmohar (*Delonix regia*)	81.0	25200 ± 711	6410 ± 410	25800 ± 1563
Peltophorumferruginum	68.1	34600 ± 1.22	2980 ± 0.09	8.62 ± 0.14
Lucerne (*Medicago sativa*)	78.6	38600 ± 0.71	14790 ± 0.24	38.3 ± 0.79
Spirulina fusiformis[b]	7.1	413000 ± 3.26	188000 ± 2.85	45.6 ± 0.92

Values are mean ± SD (μg/100 g) of five determinations.
[a] Moisture content (g/100 g) of foodstuff (mean of five determinations).
[b] Also contains γ-carotene (600 μg/100 g) and β-Cryptoxanthin (5000 μg/100 g).

small quantities of β-carotene but has large amounts of lycopene, a powerful singlet oxygen quencher (Stahl, Heinrich, Aust, Tronnier, & Sies, 2006). While drumstick leaves are a rich source of β-carotene, drumstick pods do not contain any β-carotene (Bhaskarachary et al., 1995). Notwithstanding these observations, it is interesting that Indian children consume more than 90% of their recommended daily amount (RDA) of β-carotene from vegetables.

3.3. Spices and condiments

In India, spices contribute significantly to the overall intake of β-carotene. Among the spices and condiments, nutmeg contains negligible amounts of carotenoids but its ariel (mace or japathri) is a very rich source of total carotenoids, as well as β-carotene (2170 μg/100 g). Smilax, another spice which is commonly used in rice preparations, contains significant amount of β-carotene (2130 μg/100 g). Red chilli, which is regularly used in Indian recipes, contains 1310 μg/100 g of β-carotene. Cloves (70 μg/100 g) and turmeric (60 μg/100 g) have low amounts of β-carotene. Turmeric is frequently used in Indian recipes for its colouring, flavouring and medicinal properties. Curcumin, the active principle in the turmeric works on xenobiotic metabolising enzymes (Goud, Polasa, & Krishnaswamy, 1993). Fenugreek seeds, known for their rich soluble dietary fibre content and with proven hypoglycaemic and hypocholesterolaemic effects (Ramulu & Udayasekhararao, 2006), also contain significant quantities of β-carotene (140 μg/100 g) (Table 3).

4. Unconventional sources of β-carotene

In addition to boosting the production of carotene rich fruits and vegetables in India there is a need to identify and encourage the production and consumption of unconventional sources of carotenes, to meet the current shortage of carotene-rich food. In this context, four unconventional foods (Table 4) *Gulmohar, Peltiforum, Lucern* and *Spirulina* were studied for total carotenoids and β-carotene.

Gulmohar petals contained almost twice the provitamin A levels of *Peltiforum* flowers. The flower petals of *Peltiforum ferruginum* are yellow in colour and were found to have a higher concentration of total carotenoids than the red coloured petals of *Gulmohar*. These unconventional plant sources need toxicological evaluation before they can be used as a dietary source of β-carotene. *Lucern* leaves, presently used as an animal feed, were found to be a very good source for β-carotene content (14800 μg/100 g). These rich and abundant sources of carotenoids could be processed and utilised as colouring agents or as antioxidants. The blue-green algae *Spirulina* has been identified as the richest source for provitamin A precursors. The present study revealed that in addition to β-carotene (188000 mg/100 g), the other vitamin A precursors, like γ-carotene (600 μg/100 g) and β-cryptoxanthin (5000 μg/100 g), were also present in appreciable quantities.

Thus, this study has identified rich sources of provitamin A precursors, in commonly consumed Indian foods. In view of the fact that the extent of deficiency, with respect to micronutrients like vitamin A (88%), iron (67%) and riboflavin (71%), is very high (NNMB, 2002), the database we have compiled is very useful in planning diets, which will prevent vitamin A deficiency. This study has also identified new sources of carotenoids, which can be further studied for nutritional and toxicological effects.

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