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Total Carotenoid and β-Carotene Contents of Thai Vegetables and the Effect of Processing

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ABSTRACT

Total carotenoid and β-carotene contents of 55 vegetable products and fruits commonly consumed in the northeastern part of Thailand have been determined by spectrophotometry and high-performance liquid chromatography. The vitamin A activities, as retinol equivalents, are calculated using the in vivo *conversion factors given by the World Health Organization (WHO, 1982).*

The data obtained in the present study are, in general, markedly lower than those stated in the Thai Food Composition Table of 1978.

Leaf vegetables contain considerably more carotenoids than tuberous vegetables and fruits. The distribution of carotenoids over leaves and stalks has been determined. The carotenoids of a plant are mainly deposited in the leaves which, in general, have a higher relative β-carotene content than the stalks.

The average losses of vitamin A activity as a result of local processing, i.e. cooking, frying, fermenting, sun-drying and sun-drying followed by cooking, were found to be 14, 24, 29, 44 and 60%, respectively.

INTRODUCTION

Carotenoids represent a group of aliphatic or aliphatic–alicyclic fat-soluble yellow to red coloured compounds which are synthesized *de novo* in plants

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and in some microorganisms. They occur in the green chloroplasts present in the parenchyma of the leaves and hence contribute considerably to the pigmentation in the plant kingdom. It has been estimated that nature produces about 100 million tons of this pigment per year (Isler *et al.*, 1965).

Man absorbs and stores carotenoids rather unselectively and hence they are found in liver, blood, fat tissue and in breast milk (Goodman, 1969). However, the human body is also able to alter certain carotenoids in the digestive tract or during absorption, prior to tissue storage or *in vivo* function.

The relation between dietary carotenoid intake and health has been studied by many researchers. Ong & Chytil (1983) showed the existence of an inverse relationship between cancer and dietary intake of β-carotene, while antiulcer properties of β-carotene and β-cryptoxanthin were reported by Moszik *et al.* (1983) and antiageing effects of carotenoids were demonstrated by Cutler (1984).

A well-known aspect of dietary carotenoid intake is conversion of certain carotenoids into retinol. The number of carotenoids known to occur naturally now exceeds 500, whereas the number of compounds with vitamin A activity is only about 50.

This *in vivo* conversion into retinol, which is part of the active light receptor in the rods of the retina (Marks, 1975), plays an important role in developing countries since retinol-containing dairy and other animal products are not available or are too expensive (Simpson, 1983). The main source of vitamin A activity for large groups of the population is the green leaf vegetable. In many developing countries, prolonged vitamin A deficiency occurs among young children, especially during the weaning period (Mrisho, 1981). This constitutes a public health problem due to the possibly resulting xerophthalmia, which may cause irreversible destruction of the cornea and subsequent blindness. An extensive compilation concerning the importance of vegetables in human nutrition is given by Oomen & Grubben (1978).

The vitamin A activity of vegetables cannot be established unequivocally since many factors affect the concentration and the composition of the group of carotenoids in the plant or their *in vivo* conversion into retinol. The genetics and the environment of the plant influence the occurrence of carotenoids. Interplant variations can be considerable (Blessin *et al.*, 1963). A diurnal carotenoid pattern for leaves has already been shown by Thompson (1949). Furthermore, the age of the plant, the position of the leaf on the stalk and enzymatic and photochemical processes during and after harvesting influence the carotenoids pattern. Processing also affects vitamin A activity. Losses of activity as a result of processing have been compiled by Kläui & Bauernfeind (1981).

The conversion of certain carotenoids into retinol is influenced by the animal species, the structure of the compound, its solubility, its state of isomerization and the dietary levels of carotenoids, lipids, proteins, antioxidants and absorption inhibitors. Hence no defined conversion factor per carotenoid can be given. The conversion factor in humans of β-carotene, the most active compound mentioned in the literature, varies from the theoretically highest of $\frac{1}{2}$ to $\frac{1}{8}$ (weight units of retinol proceeding from one unit of carotenoid). For dietary carotenoid mixtures it is generally acknowledged that, in terms of vitamin A activity, 6 μg of β-carotene or 12 μg of mixed dietary carotenoids are converted into 1 μg of retinol (WHO, 1982). The vitamin A activity, as a percentage of the activity of β-carotene of a large number of carotenoids obtained from bioassays, has been tabulated by Bauernfeind (1972).

As part of a nutritional intervention study (Egger *et al.*, 1985), a food consumption inquiry has been conducted among 150 families living in villages in northeast Thailand. Green leaf vegetables are their main source of vitamin A activity. Since there is evidence that methodology, to determine vitamin A activity mentioned in the food composition Tables currently in use, has led to overestimations in some cases (Zakaria & Simpson, 1979; WHO, 1982; Simpson & Tsou, 1986), the contents of total carotenoids and specific β-carotene have been determined in 55 commonly eaten vegetable products. The vitamin A activity as μg retinol equivalents per g (μg RE/g) was calculated using the above-mentioned conversion factors. Because exposure of carotenoids to heat, oxygen and light may lead to decomposition and/or structural changes which decrease activity, the effects of local processing, i.e. cooking, frying, fermenting and sun-drying, were determined. The data presented in this study have been compared with literature data.

MATERIALS AND METHODS

Sampling of fresh vegetables

The vegetables examined were bought in June–July, 1986 at the local market of Khon Kaen, a provincial capital in northeast Thailand, and analysed on the same day. Per specimen, three bunches were bought at different market stalls. In the laboratory two intact plants were selected from every bunch and dried by pressing gently between towels. Subsequently, the plants were weighed, cut in small pieces and analysed. Carrots were finely grated.

Sampling of vegetables for processing

In order to obtain two samples with equal carotenoid contents of the same specimen the vegetables were sampled as follows.

Of vegetables consisting of leaves and stalk the leaves were systematically picked off from the top to the roots and were alternately divided into two portions. After drying by gently pressing the leaves between towels, one portion was analysed directly and one after processing.

Tuberous plants, like egg plants and sugar peas, were dried with a towel and cut in symmetrical halves. Two weighed portions, each consisting of a number of halves of different plants, were analysed, one directly, the other after processing. Onions of approximately the same size were selected from the same crop and divided in two portions. Onions were fermented as intact plants.

Processing of vegetables

Processing was carried out according to the traditional local habits:

Cooking: samples of approximately 20 g were submerged for 2–8 min in boiling tap water. After cooking, the total portion was dried by gentle pressure between filter paper, cut in pieces and analysed.

Frying: samples of approximately 20 g, cut in parts suitable for consumption, were fried for 3–5 min in 5 ml of preheated soya-bean oil at approximately 200°C. During frying about 3 ml of water was added. After frying the whole portion was dried using filter paper, cut in pieces and analysed.

Fermenting: samples of approximately 20 g were brought in a glass jar. The vegetables were crushed. A small quantity of salt and a few millilitres of supernatant of already fermented vegetables were added. After approximately 1·5 days the supernatant was decanted, whereafter the fermented sample was dried using filter paper, cut in pieces and analysed.

Sun-drying: weighed portions of the leaves of the relevant vegetables were analysed straight away and after exposure to direct sun light for two days.

Analysis of total carotenoids and β-carotene

Total carotenoids and β-carotene were determined using the method described by Speek *et al.* (1986). The method is based on saponification of the sample, followed by organic extraction whereafter total carotenoids and β-carotene in the extract are determined using spectrophotometry and reversed-phase high-performance liquid chromatography, respectively.

RESULTS AND DISCUSSION

Fresh and non-processed vegetable products

The data for individual products, arranged alphabetically according to genus and species, are given in Table 1. The results for leaf and tuberous vegetables and fruits have been grouped in Table 2. In both Tables the vitamin A activity as stated in the Thai Food Composition Table (TFT) of 1978 has been included.

Striking differences are observed when comparing the measured vitamin A activity data for vegetable products with those given in the Thai Food Composition Table (Table 1). With a few exceptions the Thai Table gives higher activities for all products, probably because the relevant data were collected from rather old investigations in which less specific analytical methods were applied (WHO, 1982; Simpson & Tsou, 1986). This means that making use of the Thai Table in food consumption inquiries will lead to overestimations of the provitamin A carotenoid intake.

The percentage of β-carotene of the total content varies from 2·1 to 55%. Thus, in spite of its higher vitamin A activity, β-carotene, with exceptions for carrots and durian, contributes less to the plant's total activity than the other mixed carotenoids.

Table 2 shows that leaf vegetables contain considerably more carotenoids than tuberous vegetables and fruits. Leaf vegetables (1·2–18·8 μg RE/g, Table 2) have a higher vitamin A activity than milk (up to 1 μg of retinol/g), contain approximately the same quantity of activity as eggs (3–6 μg of retinol/g), but considerably less than cattle liver (150–1500 μg of retinol/g, Marks, 1975). The average per group of the ratios of the vitamin A activities of vegetable products as stated in the Thai Food Composition Table and as measured shows that the Thai Table generally gives remarkably higher values.

Inhomogeneity of the plant

In order to investigate the distribution of the carotenoids over leaves and stalks, the leaves of fresh and non-processed vegetables and the whole plants of the same bunch were analysed. The results are shown in Table 3.

It appears from Table 3 that carotenoids mainly occur in the leaves. In general, the leaves contain relatively more β-carotene than the other parts of the plant.

Interplant variations

In order to determine interplant variations, amaranth, celery, vine spinach and lettuce were analysed for vitamin A activity on each of four consecutive

TABLE 1
Vitamin A Activity of Commonly Eaten Fresh and Non-processed Thai Vegetable Products and Fruits

	Total carotenoid (μg/g)	*β-carotene (μg/g)*	*% β- of total*	*Calculated activity (RE/g)*	*Thai Food Table*		
					Activity (RE/g)	*Ref.*	*No.*
Leaf vegetables							
Acacia insuavis Lace cha-om (local name)	61	4·2	6·9	5·4	—		
Allium odorum Linn. Chinese chive, onion fragrant	109	8·3	7·6	9·8	5·1	1	7
Allium odorum Linn. Chinese chive	39	1·7	4·3	3·4	6·8	2	8
Amaranthus gangeticus Linn. amaranth spineless	93	19·6	21·1	9·4	38·6	1	173
Apium graveolens Linn. celery	75	7·7	10·3	6·9	—		
Azadirachta indica Juss., var. *siamensis valeton* neem tree	118	9·2	7·8	10·6	8·2	2	202
Basella alba Linn. vine spinach; Malabar nightshade	70	5·6	8·0	6·3	17·5	1	196
Brassica Chinensis Jusl. Chinese cabbage	72	9·7	13·5	6·8	7·3	1	163
Brassica Chinensis var. *parachinensis* Tsen & Lee flowering white cabbage	28	2·5	8·9	2·5	10·2	1	167
Brassica juncea Czern & Coss. pickled leaf mustard, fermented	13	1·2	9·1	1·2	—		157
Brassica oleracea Linn. var. *acephala* DC Chinese kale or collard	43	2·3	5·3	3·8	30·0	2	177
Brassica oleracea Linn. var. *capitata* Linn. cabbage	34	4·1	12·1	3·2	—		
Brassica sp. pak kard soi (local name)	71	9·0	12·8	6·7	—		
Careya sphaerica Roxb. kradon (local name)	93	7·5	8·1	8·4	—		
Centella Asiatica Urban. Asiatic pennywort	47	1·0	2·1	4·0	35·4	2	107
Coccinia indica White & Arn. ivy gourd	53	6·1	11·5	4·9	54·2	1	52
Coriandrum sativum Linn. coriander	150	19·9	13·3	14·2	14·3	1	181
Cucurbita maxima Duch. winter squash, young leaves	78	9·6	12·3	7·3	7·3	1	222
Daucus carota carrot, raw	33	18·3	55·0	4·3	55·6	3	44
Eryngium foetidum Linn. common fennel	85	44·4	5·2	7·5	—		182
Ipomoea aquatica Forsk. Chinese swamp cabbage	115	10·5	9·1	10·5	19·6	2	188
Swamp cabbage, green stalk and big leaves (wet soil)	50	8·7	17·4	4·9	4·8	2	189
Swamp cabbage, white stalk and small leaves (dry soil)	15	0·42	2·8	1·3	4·8	2	189
Lactuca sativa Linn. lettuce, unheaded	67	4·8	7·2	6·0	10·2	1	160
Leucaena leucocephala de Wit lead tree	72	1·7	2·4	6·1	4·7	2	19
Leucaena leucocephala de Wit lead tree, tender top	13	0·47	3·4	1·2	23·6	1	20
Mentha cordifolio Opiz. kitchen mint	102	7·3	7·2	9·1	10·8	1	134
Momordica charantia Linn. bitter melon leaves	164	34·0	20·7	16·5	25·4	1	126
Neptunia oleracea Lour. water mimosa	103	10·6	10·3	9·5	—	—	145
Ocimum basilicum Linn. sweet basil	92	5·1	5·5	8·1	33·3	1	139
Ocimum canum Sims. hairy basil	63	3·5	5·6	5·5	—		130
Ocimum sanctum Linn. holy basil	67	4·8	7·2	6·0	—		100
Piper sarmentosum Roxb. chaa phluu (local name)	218	8·0	3·7	18·8	47·4	2	104
Tuberous vegetables and beans							
Allium ascolonicum Linn. onion, young, complete plant	33	2·1	6·3	2·9	6·0	4	53
Brassica oleracea Linn. var. *botrytis* Linn. cauliflower	0·63	0·04	6·3	0·06	0·28	1	1
Brassica pekinensis Rupr., var. *cylindrica* Tsen & Lee celery cabbage	4·0	1·1	5·3	0·43	1·05	2	149
Cucumis sativa Linn. cucumber, not paired	0·95	0·06	6·3	0·08	0·75	4	56
Hibiscus esculentus Linn. okra or lady's finger	8·8	0·54	6·1	0·78	0·70	1	14
Luffa acutangula Roxb. angled loofah, fruit	1·7	0·47	27·6	0·18	0·15	1	98
Lycopersicon esculentum Mill. tomato, ripe	6·4	1·46	22·8	0·66	2·5	2	237
Momordica charantia Linn. bitter melon, fruit	9·6	0·50	5·2	0·84	0·55	1	243

TABLE 1—*cont.*

	Total carotenoid (μg/g)	*β-carotene (μg/g)*	*% β- of total*	*Calculated activity (RE/g)*	*Thai Food Table*		
					Activity (RE/g)	*Ref.*	*No.*
Tuberous vegetables and beans							
Parkia speciosa Hassk. sato (local name)	8·2	0·66	8·0	0·74	2·2	5	256
Pisum sativum Linn. sugar peas or garden peas	8·9	1·7	19·0	0·88	1·2	1	85
Solanum melongena Linn. egg plant, long shape	7·9	0·87	11·0	0·73	1·06	2	234
Solanum melongena sw. egg plant, round shape	5·3	0·41	7·7	0·48	1·94	2	230
Solanum torvum sw. egg plant, small and round	8·7	0·35	4·0	0·75	5·7	2	231
Solanum xanthocarpum sw. egg plant, oval shape	3·9	0·10	2·6	0·33	—		236
Vigna sinensis Savi ex Hassk. yard-long beans, green	6·8	0·44	6·6	0·60	1·7	3	73
Zea mays. corn, yellow	12·6	0·74	5·9	1·11	1·31	3	18
Fruits							
Artocarpus heterophyllus Lamk. jackfruit, mature	4·5	0·23	5·1	0·39	1·18	1	9
Carica papaya Linn. papaya, ripe	6·4	0·38	5·9	0·57	3·5	1	94
Cucurbita maxima Duch. winter squash or pumpkin	23·0	0·49	2·1	2·0	7·4	1	223
Durio zibethinus Linn. durian	3·8	1·9	50·0	0·48	3·1	2	35
Mangifera sp. mango, ripe	3·33	0·63	18·9	0·33	9·4	1	76
mango, unripe	0·62	0·10	16·1	0·06	0·55	1	74
Lagenaria siceraria Standl. bottle gourd, fruit	0·46	0·04	8·7	0·04	0·05	1	90

TFT: Thai Food Composition Table of 1978 composed of data collected from:
[1]: Food Composition Table for use in East Asia, by FAO and US Department of Health, Education and Welfare.
[2]: Division of Food Analysis, *The Bulletin of Department of Medical Science, Thailand*, Vol. 1–2, 1973, 47–67. (Thai).
[3]: *Food Composition Table by Food and Nutrition Research Center in Manila, Philippines Handbook I* (3rd revision), 1964.
[4] *Composition of Foods, Raw, Processed, Prepared*, USDA Agriculture Handbook No. 8, Revised, 1963.
[5]: Analytical results from The Analytical Research Subcommittee of the National Nutrition Committee, Thailand (Thai).

TABLE 2
Vitamin A Activity of Groups of Fresh and Non-processed Leaf Vegetables, Tuberous Vegetables and Beans, and Fruits

Group	*Vitamin A activity (μg RE/g)*			*Ratio TFT/ our data*
	Range	*Average ± SD*	*n*	*average ± SD*
Leaf vegetables				
Our data	1·2 – 18·8	7·06 ± 4·09	32	3·8 ± 4·4
Thai Food Table	4·7 – 54·2	19·07 ± 14·92	22	*n* = 22
Tuberous vegetables and beans				
Our data	0·06 – 2·9	0·72 ± 0·65	16	3·1 ± 2·5
Thai Food Table	0·15 – 6·0	1·81 ± 1·78	15	*n* = 15
Fruits				
Our data	0·67 – 2·0	0·55 ± 0·67	7	8·3 ± 9·3
Thai Food Table	0·05 – 7·4	3·6 ± 3·56	7	*n* = 7

TABLE 3
Vitamin A Activity of Whole Plants and Their Leaves

Vegetable	*Number TFT*	*Vitamin A activity (μg RE/g)*		*% β-carotene of total*	
		Whole plant	*Leaf*	*Whole plant*	*Leaf*
Coriander	181	14·2	23·2	13·3	19·6
Neem tree	202	10·6	17·4	7·8	12·5
Chinese swamp cabbage	188	10·5	9·1	24·7	26·7
Amaranth	173	9·4	28·7	21·1	20·0
Sweet basil	139	8·1	21·5	5·5	12·3
Celery	19	6·9	16·0	10·3	15·5
Chinese cabbage	163	6·8	13·3	6·7	15·3
Vine spinach	196	6·3	14·2	8·0	6·4
Hairy basil	130	5·5	16·5	5·6	7·8
Ivy gourd	52	4·9	14·4	11·5	16·4
Chinese kale	177	3·8	4·9	5·3	21·4
Swamp cabbage, white stalk and small leaves	189	1·3	19·8	2·8	50·0

days. Every day a bunch of vegetables was bought at a different market stall and analysed. From the results: amaranth, 9·3 ± 17%; celery, 6·8 ± 22%; vine spinach, 6·6 ± 17% and lettuce, 5·7 ± 9·0% (mean ± coefficient of variation, μg RE/g, $n = 4$), it can be concluded that, irrespective of seasonal variations, interplant variations are rather large. Therefore, fresh vegetables were sampled by selecting a few intact plants from three bunches bought at different stalls (Table 1).

Reproducibility of sampling vegetables

In order to establish processing effects which are expected to be of the same extent as the above-mentioned interplant variations, a method had to be found to obtain two samples with equal carotenoid contents of the relevant vegetable. Three different sampling methods were tried out. Analysis of vitamin A activity was done in duplicate on amaranth, sweet basil, Chinese chive and swamp cabbage.

A: The plants, in the form in which they are consumed or processed, were cut in pieces of 3–4 cm which were mixed. Two portions were weighed and analysed.

B: The plants were cut lengthwise through the stalk in more or less symmetrical parts. Two portions, each consisting of different halves of plants, were weighed and analysed.

C: The leaves were systematically picked off from the top to the roots and alternately divided into two portions which were weighed and analysed.

The average of the four duplicate differences was, for method A, 17% $\pm$ 7·5; for method B, 24% $\pm$ 13·5, and for method C, 1·9% $\pm$ 1·0 (percentage of the average value $\pm$ SD, $n = 4$). Based on these results it was decided to apply method C to obtain samples for the determination of the effects of processing. The high duplicate differences obtained with methods A and B can be explained by the finding that stalks contain a considerably lower amount of carotenoids than the leaves while they contribute rather a lot to the weight of the plant.

Effects of processing

A number of vegetables were sampled as described above and analysed fresh and after processing according to the local habits. The results are given in Table 4.

After cooking the water was somewhat green. Probably, this resulted from migration of green chloroplasts from the leaves into the water. Loss of carotenoids is obvious as both chloroplasts and carotenoids occur in the parenchyma of the leaves. Our data concerning the losses of vitamin A activity are, in general, comparable with literature data as compiled by Kläui & Bauernfeind (1981).

The effect of cooking on the vitamin A activity (average loss of 14%) agrees very well with the finding of Sood & Bhat (1974) who reported an average loss of 13% $\pm$ 2·6 (mean $\pm$ SD) for eight leaf vegetables cooked according to three comparable methods. Sweeney & Marsh (1971) observed losses of activity of 15 to 20% in a similar experiment with green vegetables.

Ogunlesi & Lee (1979) reported an average loss of vitamin A activity of 15% for carrots after cooking for 30 min at 116°C. They took into account losses as a result of decomposition as well as of the conversion of all-*trans*- to less active *cis*-isomers. Although their three-step separation method probably results in a more accurate assay of the vitamin A activity, it is not suitable for large-scale determinations as the method is very complex, and thus time-consuming.

All five types of processing mentioned in Table 4 cause relatively larger losses of β-carotene, probably because this compound is less heat and UV-light stable than the other carotenoids.

The highest average effect is caused by sun-drying (44% loss) and sun-drying followed by cooking (60% loss). Sun-dried vegetables are always cooked before consumption. Cooking fresh vegetables causes vitamin A

TABLE 4
Influence of Processing on Total Carotenoids and β-Carotene Contents and Vitamin A Activity of Vegetable Products

Vegetable	*Number TFT*	*Min*	*Total carotenoid*	*β-carotene*	*Vitamin A activity*
			Carotenoids as percentage of fresh after cooking		
Bitter melon leaves	126	5	91	89	91
Coriander	181	4	93	85	91
Sweet basil	139	2	89	68	88
Celery		4	81	84	81
Vine spinach	196	8	66	89	68
Lettuce, unheaded	160	4	89	77	88
Hairy basil	130	2	91	76	90
Cha-om (local name)		4	99	69	90
Swamp cabbage	189	4	94	50	91
Average ± SD, $n = 9$			88 ± 10	76 ± 13	86 ± 8
			Carotenoids as percentage of fresh after frying[a]		
Chinese swamp cabbage	188	4	92	76	88
Chinese cabbage	163	4	99	84	97
Chinese kale	177	4	67	24	59
Chinese chive	8	4	66	19	57
Cabbage (*B. oleracea* var. *capitata* Linn.)		4	90	57	82
Sugar peas	85	4	65	92	70
Average ± SD, $n = 6$			80 ± 16	59 ± 31	76 ± 16
		Day	*Carotenoids as percentage of fresh after fermenting*		
Chinese chive	7	1·5	69	95	70
Whole onion plant	53	1·5	98	78	97
Pickled leaf mustard	157	1·5	84	67	82
Egg plant, round shape	230	1·5	35	22	34
Average ± SD, $n = 4$			72 ± 27	66 ± 31	71 ± 27
			Carotenoids as percentage of fresh after sun drying		
Neem tree	202	2	64	53	63
Neem tree, duplicate		2	68	56	66
Amaranth[b]	173	2	49	50	49
Sweet basil[b]	139	2	45	39	45
Average ± SD, $n = 4$			57 ± 11	50 ± 7	56 ± 10

TABLE 4—*contd.*

Vegetable	*Number TFT*	*Min*	*Total carotenoid*	*β-carotene*	*Vitamin A activity*
			Carotenoids as percentage of fresh after sun drying (2 days) followed by cooking (4 min)		
Amaranth	173		43	37	40
Amaranth duplicate			41	38	39

[a] In a blank experiment the soya-bean oil used for frying was checked for the absence of vitamin A activity ($<0{\cdot}2\,\mu g$ RE/g).
[b] These vegetables are usually not sun-dried.

activity losses of 14% ± 8 (av. ± SD) while higher losses are involved in cooking of sun-dried vegetables, i.e. 25%, probably on account of the lower integrity of the cell walls.

CONCLUSION

As many food composition Tables in the region are composed using the same sources, it may be expected that generally too high values for the vitamin A activity of vegetable products are reported. The Tables should be revised using more specific analytical methods. Furthermore, processing of vegetable products causes a considerable loss of vitamin A activity, which should be taken into account in using food composition Tables for the calculation of vitamin A intake.

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REFERENCES

Bauernfeind, J. C. (1972). Carotenoid vitamin A precursors and analogs in foods and feeds. *J. Agric. Food Chem.*, **20**, 456–73.

Blessin, C. W., Brecher, J. D., Dimler, R. J., Grogan, C. O. & Campbell, C. M. (1963). Carotenoids of corn and sorghum. III. Variation in xanthophylls and carotenes in hybrid, inbred and exotic corn lines. *Cereal Chem.*, **40**, 463–72.

Cutler, R. G. (1984). Carotenoids and retinal: Their possible importance in determining longevity of prunate species. *Proc. Nat. Acad. Sci.*, **81**, 7627–31.

Egger, R. J., Wedel, M. & Schreurs, W. H. P. (1985). In: *Health problems in Asia and the Federal Republic of Germany. How to solve them?* (Schelp, F. P. (Ed)), *Medezin in Entwicklungsländern*, Vol. 21, Verlag Peter Lang, Frankfurt am Main, 307–14.

Goodman, D. S. (1969). Biosynthesis of vitamin A from β-carotene. *Amer. J. Clin. Nutr.*, **22**, 963–5.

Isler, O., Ruegg, R. & Schwieter, U. (1965). Carotenoids as food colorants. *Pure Appl. Chem.*, **14**, 245–63.

Kläui, H. & Bauernfeind, J. C. (1981). Carotenoids as food colors. In: *Carotenoids as colorants and vitamin A precursors. Technological and nutritional applications* (Bauernfeind, J. C. (Ed)), Academic Press, New York, London, 156.

Marks, J. (1975). *A guide to the vitamins. Their role in health and disease.* MTP Co. Ltd, Lancaster, UK, 39–49.

Moszik, G., Monika, B., Tibor, J., Fancisco, M., Joszef, S. & Toth, G. (1983). *Taplakozastud. Helyzete Feladatia Magyarorszagon*, 8, 781.

Mrisho, F. H. (1981). The importance of vitamin A in weaning food. In: *Practical considerations for childfeeding in East, Central and Southern African countries*, Workshop Arusha (Tanzania), 152.

Ogunlesi, A. T. & Lee, C. Y. (1979). Effect of thermal processing on the stereoisomerisation of major carotenoids and vitamin A value of carrots. *Food Chem.*, **4**, 311–18.

Ong, D. E. & Chytil, F. (1983). In: *Vitamins and hormones* (Aurbach, G. D. (Ed)), Academic Press, New York, 105.

Oomen, H. A. P. C. & Grubben, G. J. H. (1978). *Tropical leaf vegetables in human nutrition.* Royal Tropical Institute, Amsterdam, Tesink, Zutphen, The Netherlands.

Simpson, K. L. (1983). Relative value of carotenoids as precursor for vitamin A. *Proc. Nutr. Soc.*, **42**, 7–17.

Simpson, K. L. & Tsou, S. C. S. (1986). Vitamin A and Provitamin A Composition of Foods. In: *Vitamin A deficiency and its control.* (Bauernfeind, J. C. (Ed)), Orlando, Academic Press (In press).

Sood, R. & Bhat, C. M. (1974). Changes in ascorbic acid and carotene content of green leafy vegetables on cooking. *J. Food Sci. Tech.*, **11**, 131–3.

Speek, A. J., Temalilwa, C. R. & Schrijver, J. (1986). Determination of β-carotene content and vitamin A activity of vegetables by high-performance liquid chromatography and spectrophotometry. *Food Chem.*, **19**, 65–74.

Sweeney, J. P. & Marsh, A. C. (1971). Effect of processing on provitamin A in vegetables. *J. Am. Diet. Ass.*, **59**, 238–43.

Thompson, C. R. (1949). The carotene content of several varieties and strains of alfalfa. *Agron. J.*, **41**, 294–7.

WHO (1982). *Control of vitamin A deficiency and xerophthalmia.* World Health Organization, Technical Report Series No. 672: Report of a joint WHO/UNICEF/Helen Keller International/IVACG meeting.
Zakaria, M. & Simpson, K. (1979). Use of reversed-phase high-performance liquid chromatographic analysis for the determination of provitamin A carotenes in tomatoes. *J. Chromatogr.*, **176**, 109–17.