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Use Of ß-Carotene Rich Foods For Combating Vitamin A Deficiency

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Vitamin A deficiency is one of the major nutritional problems in some parts of India. Even as at present, more than 85 percent of the intake of vitamin A in the country is being derived from ß-carotene and other carotenes with provitamin A activity, present in the traditional dietaries. Yellow fruits and green leafy vegetables (GLV) are the main sources of ß-carotene and other carotenes. These fruits and vegetables, although not a source of energy, contain useful amounts of minerals and other vitamins, particularly ascorbic acid. The prevailing vitamin A malnutrition in India reflects the inadequate intake of these ß-carotene rich foods. Our efforts for combating vitamin A deficiency must, therefore, be logically directed towards augmenting the availability and intake of these relatively inexpensive foods.

SOURCES OF VITAMIN A ACTIVITY

Vitamin A is essential for normal vision and growth. It has also other systemic functions essential for maintaining good health. Preformed vitamin A or retinol which is present exclusively in animal foods possesses the highest vitamin A activity and is utilised directly in the body. On the other hand, provitamin A compounds like ß-carotene and other carotenes have to be converted into retinol in the body before they can function as vitamin A. Although theoretically one molecule of ß-carotene should yield two molecules of retinol, under physiological conditions, the conversion efficiency is only 50 percent, i.e., 1 µg ß-carotene yielding only about 0.5 µg of retinol. Other carotenes that is δ- γ- and ß-carotene derivatives are converted into vitamin A with much less efficiency (Table 1). The provitamin A activity of carotene-containing plant foods (fruits and vegetables) will depend upon the proportion of these carotenes present in the carotenoid pigments of these foods[27]. Green leafy vegetables have the highest content of ß-carotene, 80 percent or more of total carotenes, while in the other vegetables and fruits, ß-carotene forms only 15-70 percent of total carotene[15] (Table 2). The bioavailability of carotenes (Table 3) from plant foods (fruits and vegetables) varies from 30 to 80 percent[5,6,13,14,16] with the result, the net vitamin A activity of carotene rich foods constitutes only 15 to 40 percent of ß-carotene equivalents present in these foods.

Table 1
Relative activity of carotene

Carotenoids	Relative Activity Percent
ß - carotene	100
δ - carotene	50-54
γ - carotene	42-50
Cryptoxanthin	50-60
ß - carotene epoxides	20-50
Zeaxanthin	Inactive
Lycopene	"

Table 2
Distribution of carotenes in foods

Source	Percent distribution	
	β-carotenes	Other carotenes*
Green vegetables	80	20
Amaranth	96	4
Deep yellow vegetables and yellow fruits	85	15
Carrots	69	31
Mango	55	45
Papaya	15	85
Tomato	55	45
Spirulina	60	40
Red palm oil	65	35

** with provitamin A activity*

HUMAN REQUIREMENT OF VITAMIN A

Human requirement of vitamin A has been determined through long-term depletion and repletion and radiolabelled retinol turnover studies in human volunteers[8]. Based on these studies, the human requirement of vitamin A (retinol) has been defined[8] at two levels, a minimal or basal level of intake of vitamin A to fulfil its functions and prevent deficiency symptoms and a safe level to permit, in addition, adequate liver storage of retinol. The relative requirement of retinol (µg/kg) is the highest during infancy and it gradually decreases with age till the adult requirement is reached. Based on these data, dietary allowances of vitamin A for Indians have been recently recommended[12], both in terms of retinol and ß-carotenes. The requirement and RDA of vitamin A for Indians at different ages in terms of both retinol and ß-carotene are

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given in Table 4. The requirement figures have been computed from the requirement per kg at different ages[8] and the corresponding body weights of well-to-do Indians[12]. Vitamin A requirements of Indians have also been defined in terms of β-carotene equivalents by assuming that on an average, only 50 percent of carotenes in vegetables and fruits are bioavailable and one mg of absorbed β-carotene yields 0.5 µg of retinol in the body. The net retinol equivalent of 1 µg of dietary β-carotene is thus 0.25 µg.

Based on retinol and vitamin A requirement and the current population and its age distribution, per caput and total requirement of retinol and β-carotene have been computed and these values are also given in Table 4. These values are used for estimating the total β-carotene requirement at the national level and its availability through the carotene rich foods currently grown in India.

SOURCES OF CAROTENES

The rich sources of carotenes with provitamin A activity are fruits and vegetables. Of these, yellow fruits like mangoes[4], and green leafy vegetables[1,21] are the richest sources, and oranges, papaya, carrots are moderate sources of β-carotene. The other vegetables and fruits have too low a level of β-carotene to make any significant contribution to the dietary intake of β-carotene. Foods rich in β-carotene[21] which can make a significant contribution to dietary intake of provitamin A are shown in Table 5.

It is seen from this table that green leafy vegetables and ripe mangoes are the richest sources of β-carotene with content ranging from 25-100 µg/g. The average β-carotene content of mangoes being 25 µg/g and that of GLV 50 µg/g. The advantage of using GLV as a source of β-carotene is that it is also a good source of iron, Ca, vitamin C and folate. Apart from β-carotene from fruits and vegetables, some amount of retinol is also derived from milk and eggs.

The carotene content of a given food varies according to the variety. For example, mango varieties have β-carotene which range from 20 µg to 130 µg/g[4]. Similarly, hybrid varieties of some vegetables can have carotene two to five folds higher than that of an ordinary variety. Thus β-carotene content of the ordinary variety of tomato (pusa ruby) contains only 4-5 µg/g, while some of the hybrid varieties have 20-25 µg/g[24]. Similarly some of the hybrid varieties of carrot[2] and papaya[9] have a much higher content of β-

Table 3

Absorption of carotenes from different sources in human subjects

Source	Subjects	Percent Absorption β-carotene	Percent Absorption Total carotenes	Ref.
Pure β-carotene	Adult	98.8	97.7	16
	Children	85.4	—	13
Amaranth leaves	Adult	75.7	58.1	16
	Children	70.2	75.1	13
	Children	61.4	—	14
Fenugreek leaves	"	59.1	—	5
Drumstick leaves	"	61.0	—	5
Leaf protein concentrate	"	76.7	—	14
Spirulina		55.8	—	17
Papaya	Adults	90.9	45.8 (a)	16
	Children	77.0	—	6
Carrots	Adults	81.1	35.5 (a)	16
Diet with mixed carotene source	Adults	—	33.4	16

(a) δ-*carotene*

Table 4

Retinol and β-carotene requirements and RDA for Indians (µg/day)

Group	Age Years		Basal requirements Retinol	Basal requirements β-carotene	Safe requirement Retinol	Safe requirement β-carotene	RDA ICMR, 1990 Retinol	RDA ICMR, 1990 β-carotene
Infants	0-1		181	724	351	1404	350	1420
Children	1-6		202	808	403	1612	400	1600
	6-10		253	1012	405	1620		
	10-12		291	1164	490	1960		
	12-15		351	1404	540	2160		
	15-18	M	336	1344	512	2048	600	2400
	15-18	F	299	1196	456	1824		
Adults	18 +	M	288	1142	550	2200		
		F	240	960	465	1860		
Per caput requirement			269	1075	489	1965	573	2291

Table 5

β-carotene-rich vegetables and fruits commonly consumed

β-carotene content µg/g		Names of vegetable and fruits
5 - 10	GLV:	Lettuce; celery stalk, onion stalk
	Other vegetables:	Green pepper, cow-pea pod; tomato (ordinary variety)
	Fruits:	Papaya (ordinary variety)
10 - 25	GLV:	Bathua leaves; fenugreek; lopomea; mint; parappukeerai; ponnanganni; rape plant leaves; parsley
	Other vegetables:	Kankoda, carrots, hybrid tomatoes
	Fruits:	Papaya (hybrid); mango
25 - 50	GLV:	Amaranth spinosa; ambat chukka; celery leaves; gogu; khol-khol green; mustard leaves; safflower leaves
	Fruits:	Mango; papaya (hybrid)
50 - 100	GLV:	Agathi; amaranth paniculatus; amaranth gangeticus; betel leaves; beet green; carrot leaves; coriander leaves; chekkur manis; colocasia leaves; cow-pea leaves; curry leaves; drumstick leaves; fetid cassia-fresh; mayalu; table radish leaves; shepu; spinach; turnip greens
	Fruits:	Some varieties of mangoes
200 - 500	Dried GLV; Spirulina; LPC; mango pulp powder; red palm oil	

Botanical names and Indian language names of these vegetables and fruits are given in Ref. 21.

carotene than the ordinary variety. Development of hybrid varieties can be one of the important approaches to increase β-carotene availability by improving significantly the β-carotene content of some of the commonly consumed vegetables and fruits like tomato, carrot and papaya.

Some very rich sources of β-carotene with contents varying from 100 to 500 μg per g are dehydrated GLV leaf protein concentrate (LPC), crude red palm oil, dried algae like spirulina, and mango powder. Dehydration of green leaves will reduce bulk and can be preserved and transported over a long period if protected from sunlight and oxygen. Leaf protein concentrate can be prepared with suitable technology to retain most of the β-carotene[3]. This LPC can be promoted as a concentrated source of carotene and other vitamins instead of as a source of protein. Mango powder can be prepared from surplus mangoes during the mango season when there is a glut. Spirulina can not only be a rich source of β-carotene but also a good source of riboflavin[17]. Red palm oil can be used as a cooking medium by itself or after blending with other oils and can serve as a rich source of provitamin A.

One of the problems with the natural source of β-carotene is the rapid loss of β-carotene on drying and storage. Sun drying of GLV and its subsequent storage have been reported to result in considerable loss (40-90 percent) of β-carotene[5, 26]. However, proper pretreatment of the green leaves before drying and storage under proper conditions can prevent this loss of β-carotene[3]. In case of spirulina, it has been observed[7] that spray-drying and subsequent storage results in a substantial loss of β-carotene. It is, therefore, essential that appropriate processing and storage technology should be developed to minimise the loss of β-carotene from concentrated sources like dehydrated GLV, LPC and spirulina for their use as effective agents in controlling vitamin A deficiency in the community.

Estimates of total availability of β-carotene and retinol from all the vitamin A containing foods like fruits, vegetables and other plant foods and animal foods like milk and eggs currently produced in the country are given in Table 6.

It is seen from the table that of the total β-carotene available from all sources in the country, 95 percent is derived from fruits and vegetables; and of this, 90 percent is contributed by GLV (52 percent) and mangoes (38 percent). Animal foods like milk and eggs which are produced in the country in fair quantities also contribute to vitamin A availability mainly in the form of retinol and to a small extent as β-carotene. Of the total retinol equivalents available from all sources, both vegetable and animal, 28 percent is contributed by milk (22 percent) and eggs (6 percent), and the remaining 72 percent from vegetable sources of which GLV (39 percent) and mangoes (28 percent) together account for 67 percent. Among high income groups who consume plenty of milk and other animal foods, nearly 30-50 percent of vitamin A intake may be contributed by animal foods. On the other hand, among the poor income groups whose milk intake is low (50 ml), 90 percent vitamin A intake is derived from β-carotene from plant foods.

Table 6

Estimated annual availability of β-carotene and retinol from foods

Source	Vitamin A content (tons)			
	β-carotene	Percent contribution	Retinol* equivalent	Percent contribution
Fruits				
Mango	140.0	38.0	35.0	28.2
Orange	7.4	2.0	1.9	1.5
Papaya	1.5	0.4	0.4	0.3
Total fruits	148.9	40.4	37.3	30.0
Vegetables				
GLV	191.3	51.9	47.8	38.6
Tomato	5.3	1.4	1.3	1.1
Other vegetables	5.8	1.6	1.5	1.2
Roots + tubers	3.7	1.0	0.9	0.7
Total vegetables	206.1	55.9	51.5	41.6
Spices/condiments	4.3	1.2	1.1	0.9
	(Retinol)			
Animal foods				
Milk	3.1 (51.6)	0.8	27.4	22.1
Egg	6.2 (7.4)	1.7	6.8	5.5
Total animal foods	9.3	2.5	34.2	27.6
Total available	368.6		124.1	
Per caput μg/day	1196 μg/day		428 μg/day	

* Retinol + β-carotene in case of animal foods and β-carotene in case of plant foods.

VITAMIN A RESOURCES

The availability per capita of β-carotene is only 1190 μg/day or of retinol equivalent is 400 μg per day. When compared to per capita requirements as per RDA[12], β-carotene available from all food sources appears inadequate. However, data in Table 6 are only *very rough estimates* and do not take into account the rich array of relatively less well known β-carotene rich foods in the country.

There are also socio-economic-related factors for the unequal distribution of these β-carotene/retinol rich foods. A large proportion of the population of the lower socio-economic groups suffers from inadequate intake and hence deficiency of vitamin A. This is indeed borne out by the data from the National Nutrition Monitoring Bureau (NNMB) and other agencies during the 1970s and '80s[18,19].

FRUITS AND VEGETABLES

India is the second largest producer of vegetables in the world next only to China, and the third largest producer of fruits, next to the U.S.A. and Brazil. Production of fruits and vegetables has increased several fold during the last two or three decades, the current production (1987-88) is around 70 million tons. Of this, about 45 million tons are vegetables including roots and tubers and about 25 million tons are fruits. The Eighth Plan targets are 62 million tons of vegetables and 34 million tons of fruits [23]. Estimated production figures for different vegetables and fruits are given in Table 7. The production figures for GLV are not available, but the figures given in the table were computed from the per capita consumption of GLV and the current population figures. Nearly 53 percent of the vegetables is accounted for by potatoes, onions and other tubers, 31 percent by other vegetables and only 16 percent by GLV. Among fruits, mangoes account for 38.5 percent and 7 percent is accounted for by other carotene containing fruits like oranges and papaya. Estimates of GLV production in the country are not available. GLV has not received the attention it deserves as a horticultural crop in our country.

The available figures of production of horticultural products are only estimates. There is a need to collect accurate information on their current production and future potential.

Adequacy of production: Impressive as these production figures of fruits and vegetables are, they are inadequate to meet the minimal nutritional needs of our population. One of the reasons for this inadequacy is that in the current production, non-carotene-containing crops predominate. There is also a considerable loss of fruits and vegetables in our country during post-harvest handling, like storage, transportation, etc. Such losses are estimated to be 25-30 percent [11]. Taking the current production and post-harvest losses into consideration, per capita availability and their contribution to ß-carotene intake are also given in Table 7. It can be seen that the net per caput ß-carotene available from fruits and vegetables currently produced in India is only 1160 µg. However, these figures could be under-estimates as they do not include less well known green leafy foods. Of these horticultural crops, the major sources of ß-carotene are only mangoes and GLV accounting for 40 percent and 54 percent respectively.

Table 7

Estimated availability of fruits and vegetables and their contribution to ß-carotene availability per caput[a]

Source	Production level (million tons)	Retail level (million tons)	Per capita per day (g.)	ß-carotene (µg/d.)
Fruits				
Mango	9.2 (13.0)[c]	6.9	22.4	455 (643)
Orange	1.35	1.0	4.4	32
Papaya/yellow fruits	0.35	0.3	1.0	6
Other non-carotene containing fruits	13.00	9.8	31.8	0
Total	23.9	18.0	59.6	492
Vegetables				
Roots-tubers	23.4	17.6	57.1	12
GLV[b]	6.8 (15.0)[c]	5.1	16.6	623 (1374)
Tomato	2.0	1.5	4.9	17
Other vegetables	11.7	8.8	28.6	18
Total	43.9	33.0	107.2	670
Total fruits and vegetables	67.8 (79.8)[c]			1162 (2102)

(a) From National Horticultural Board.
(b) GLV production figures were not available but estimated from average intake.
(c) Estimated production required to meet vitamin A needs.

In order to achieve nutrition security in terms of providing enough ß-carotene to our population to prevent vitamin A deficiency, horticultural crop production should be substantially increased. This can be achieved by increasing the production of fruits and vegetables by another 12 million tons per annum. Of this, four million tons should be fruits, mostly yellow fruits like mangoes and papaya, and eight million tons of vegetables, mostly green leafy vegetables. This means the total annual production of GLV should be in the neighbourhood of 15 million tons and of mangoes and papaya 14 million tons.

Special efforts are required to boost the GLV production to this level and create a demand for it. The proposed level of production of horticultural crops will only provide per caput 70 g fruits, 35 g GLV and 35 g of other vegetables and 55 g of roots and tubers which are very modest nutrition goals indeed. In order to maintain the availability and consumption of fruits and vegetables at this level by the turn of the century, the total production should reach around 100 million tons, of which 60 million tons should be vegetables, of which GLV should be 18 million tons, and 40 million tons fruits, of which yellow fruits should be 17 million tons. It is possible to reach this target once the current constraints in horticultural crop production are removed and the pattern of vegetable production is reoriented towards more production of ß-carotene rich vegetables (GLV) and fruits (mangoes).

PRODUCTION CONSTRAINTS

Although India is a leading producer of fruits and vegetables, several constraints in the production of these horticultural crops have been identified [20,22,28] but for which the production of these horticultural commodities could have been much higher. Some of the important constraints affecting the production and availability of fruits and vegetables in the country are:

Post-harvest losses: The current practice of collection, packaging and transportation suffers from a number of drawbacks which result in an estimated loss of 25-30 percent of horticultural produce. These commodities are packaged in a traditional way which is mostly unscientific and transported by head load, bullock carts, trucks and rail, the latter two being used for long distance haulage. There are no adequate cold storage facilities either at the point of production or at the terminal points. Only some limited cold storage facilities exist at a few terminal points, namely the metropolitan cities which are not only grossly inadequate but mostly utilised for storing potatoes and onions.

The present limitations of post-harvest handling of the horticultural commodities are widely recognised[20,22,28]. Poor grading and packaging seem to be a major reason for spoilage of fruits and vegetables. Appropriate packaging technologies to reduce the spoilage during transportation and storage have been discussed [29].

It is visualised that, even without increasing production, improvement in grading, storage and packaging using modern technology will result in considerable reduction in losses which will result in additional availability of fruits and vegetables. Even if the present losses are reduced by half, the availability of fruits and vegetables can easily increase by another eight million tons.

Marketing of horticultural commodities: The traditional marketing of fruits and vegetables currently in vogue in the country neither benefits the grower nor the consumer. The trade is mostly in the hands of middlemen who exploit both the grower and the consumer. In a sample survey carried out by the Indian Institute of Horticulture Research, Bangalore, it has been computed that in our overall retail price of the vegetables 50.5 percent constitutes the commission charges and 37.6 percent accounts for transportation[11].

By marketing these products through co-operatives, the retail price of vegetables and fruits can be significantly brought down. The commodities which arrive at the cities are auctioned to the retailers at the market yard under the supervision of a regulated marketing agency. There are no cold storage facilities, at the production point nor at the terminal point, which the grower can make use of to store his produce to sell at a fair price.

Also the present system of distribution of fruits and vegetables is mostly confined to metropolitan cities and large towns leaving vast rural areas whose needs out of this system are equally important. There are plans to let the cooperatives take over the collection and distribution of these commodities[11]. NDDB has come forward in a big way to market fruits and vegetables. These efforts of a national agency for the marketing of fruits and vegetables should not be confined to metropolitan cities like Delhi and Bombay but should cover towns and villages where most people live and who, from a nutrition point of view, are in a greater need of these commodities. There is, therefore, urgent need to build a vast network of distribution points, with wholesale and retail outlets to cover the four million villages and towns throughout the country. The existing facilities at the market yard also need considerable improvement.

There is considerable discussion on exports of fruits and vegetables. It must be realised that while nutrition security is far from being fulfilled in the country at the current production level, it is unrealistic to boost exports before meeting fully the internal needs.

Low productivity: Although India is a leading country in the world in the production of fruits and vegetables, its productivity is quite low as compared to the developed ones or even some of the developing countries like China and Brazil[23]. The average production of fruits in India is 9.8 tons/hectare as compared to 17-30 tons/hectare in other countries. The productivity of various vegetables in India ranges from 2.8 to 9.5 percent tons/hectares while in other countries it is two or three times higher.

A number of factors have been identified as being responsible for the low productivity[20,22,28]: (a) Low priority given to horticultural crops by the farmers. (b) Seeds used are mostly of an ordinary traditional variety and not the high yielding hybrid variety. The production and supply of such high quality seeds are grossly inadequate. (c) Fertiliser used is mostly farm yard manure and adequate chemical fertilisers which can boost production are not used. (d) Pest control measures are not used or if used at all they are employed inadequately. Most of the current production technology in raising horticultural crops is a traditional one. Horticultural experts are confident that by using modern agricultural techniques, production of fruits and vegetables can be considerably increased in our country. Even by increasing our productivity by 50 percent more (viz. 15 tons per hectare), our total production of horticultural crops can be boosted to 100 million tons.

Production pattern: As was pointed out earlier, the present production pattern of fruits and vegetables and related horticultural research do not adequately cover GLV which is so important to meet the vitamin A needs of our population. The current research and production efforts should be shifted to these commodities like GLV and yellow fruits to achieve self-sufficiency in vitamin A sources and provide nutrition security to the nation.

FUTURE STRATEGIES

The future strategies for increasing production of fruits and vegetables should be given a nutrition orientation in order to achieve adequate supply of ß-carotene to prevent vitamin A deficiency in the country. Thus while increasing production of horticultural crops, more emphasis should be placed on GLV and yellow fruits, the main sources of ß-carotene. Also an equitable distribution of fruits and vegetables should be ensured by having a large number of wholesale and retail outlets to cover all the villages and towns in the country. It is also necessary to collect more reliable data on the present production of fruits and vegetables and their distribution which is so essential for a realistic planning of their increased production and distribution. Some of the important strategies for increasing the availability of fruits and vegetables to ensure nutrition security in the country are:

● **Increase the current production and availability:** By reducing post-harvest losses by improved handling of the horticultural commodity, by employing modern scientific grading, packaging, transportation and storage; and improving the productivity by the use of a package of inputs like hybrid seeds, chemical fertilisers and plant protection measures.

● **Horticulture as an income generation activity:** Home gardening currently advocated to promote consumption of vitamin A foods for combating vitamin A deficiency cannot be expected to contribute significantly to the massive efforts needed to increase production of ß-carotene rich fruits and vegetables, as our earlier experience with ANP indicates. Production through home gardening efforts can only marginally supplement the massive production effort needed to bridge the gap in the availability of ß-carotene rich foods which can be effectively met only through systematic development of horticultural farming. However, home gardening activity can best be utilised as an educational activity to promote consumption of GLV and yellow fruits.

On the other hand, promoting horticulture on small plots of land as an income generation activity and a poverty alleviation programme among landless labourers, marginal farmers and share croppers in the rural area, with a package of inputs as subsidy, can help to boost production of horticultural produce. This effort should be backed by an effective collection and marketing system of vegetables and fruits produced by these small farmers. Formation of the Horticultural Crop Growers' Cooperative on the lines of milk producers' cooperatives will help in ensuring a fair return to the farmers.

Special efforts to boost availability of GLV: As was discussed earlier, the current production of GLV, the main source of ß-carotene for a large segment of our population is very much below requirement and it requires considerable boosting. Some of the strategies to improve GLV production are:

● Small farmers can be encouraged to grow GLV on their small plots as a part of income generation activity.

● Oilseed, spice and fibre crops like rape/mustard, coriander and fenugreek, raj keera and mesta are cultivated as commercial crops over large areas for their seeds. The leaves of these crops are edible and are also used commonly as GLV. Judicious harvesting of the leaves from these crops without affecting the seed yield can be a good potential source of GLV.

● GLV and other vegetables can be encouraged to be grown as inter-crops in paddy, wheat and sugarcane fields as a source of additional income to farmers.

● Growing of trees like drumstick, Agathi, etc. as a part of tree planting activity. The leaves of these trees can be a perennial source of GLV.

MARKETING

- Any national plan for increasing production of fruits and vegetables should be backed up by an efficient and widely distributed network of marketing which can be largely in the cooperative sector.

- Seed industry for producing adequate quantity of high quality seeds, and hybrid seeds for horticultural crops should be established.

- There should be an active nationwide effective nutrition education programme for encouraging consumption of fruits and vegetables and particularly GLV to create a demand for them when their production increases.

Processed foods as rich sources of ß-carotene: Dehydrated GLV, leaf protein concentrate, spirulina, mango juice powder, red palm oil are all very rich sources of ß-carotene and contain 200-500 µg/g. These can serve as additional sources of ß-carotene besides fruits and vegetables, particularly for the prevention of vitamin A deficiency among the vulnerable groups. GLV, LPC and mango powder can be produced during the glut season to be used in the lean season. The CFTRI has the necessary technology for all these products. The production of LPC may have to be reoriented as a ß-carotene source and technology suitably modified to maximise carotene content. Spirulina can be grown commercially in village ponds or under artificial conditions. Methods for its incorporation in our culinary practice must be worked out. In order that these products can be used as potential sources of ß-carotene, the technology of their production should include appropriate processing and packaging to minimise losses of ß-carotene during transportation and storage.

Red palm oil is another rich source of ß-carotene which can be used directly as an edible oil or after blending with other oils. Recent studies at NIN have shown[17] that it is safe and acceptable. This source will be ideal for future exploitation since palm oil production is envisaged as a strategy to meet the edible oil shortage in the country.

In the ultimate analysis, it is only through the augmentation of production and intake of ß-carotene rich indigenous food, for which bright prospects do exist, that we can hope to achieve an enduring and meaningful answer to the problem of vitamin A deficiency in the country. It will be poor strategy to continue to rely indefinitely on the use of massive doses of synthetic vitamin A for this purpose.

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