Carrots and Other Horticultural Crops as a Source of Provitamin A Carotenes

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Horticultural crops are the main world source of vitamin A. in the form of provitamin A carotenes. Since world vitamin A deficiency is the most common specific dietary deficiency (Pitt, 1979), improvement of horticultural crop nutritional quality and productivity and increased consumption of horticultural crops can make an important contribution to improved human health.

World vitamin A consumption

It has been estimated that. each year, 8 to 10 million children suffer vitamin A deficiency. With this, mucosal epithelial cells deteriorate to increase the risk of respiratory infection, diarrhea, and other communicable disease 2- to 3-fold. Furthermore, 1 million children (especially 6-month- to 6-year-olds) suffer severe vitamin A-deficiency eye disease, (xerophthalmia), 250,000 of these lose their sight, and 150.000 of these die within several months of becoming blind (USAID, 1989). The greatest incidence of vitamin A deficiency occurs in Africa, Asia, and parts of Latin America and the Near East. Although eye disease due to vitamin A deficiency is rare in developed areas, it is thought that 30% of the U.S. population is "at risk", since <70% of the recommended daily allowance of vitamin A is consumed (USDHEW, 1968-70; Briggs, 1981). Furthermore, carotene and vitamin A consumption also have been associated with a significant reduction in the incidence of cancer (e.g., Halter. 1989, Ziegler, 1989). Thus, vitamin A and provitamin A carotenoids affect several diverse aspects of human health (Bendich and Olson, 1989).

The daily vitamin A intake recommended by the FAO is 250 to 400 retinol equivalents (RE) for children. 575 to 725 RE for adolescents. and 750 RE for adults (higher for pregnant and lactating women) (FAO, 1982). The food supply of retinol equivalents in 198686 provided 803 RE per caput per day worldwide. Yet the daily per caput supply was 90% of the recommended adult intake (675 RE) for developing countries overall (75.4% of the world population), <500 RE in 30 countries, <400 RE in 18 countries, and <300 RE in 11 countries (FAO, 1988). Most of the countries with a markedly deficient retinol supply are in Africa, where the average retinol availability has dropped slightly since 1969-71. In Malawi, Swaziland, Zambia, and Zimbabwe, retinol availability has dropped 10% to 18% in this time period. This is in contrast to Asian countries with historically low retinol availability, where supplies have generally risen since 1961-64. in some cases dramatically (e.g., Indonesia. Malaysia. Pakistan, and Saudi Arabia). Several Central and South American countries also have experienced a reduction in retinol supply since 1961-64 (e.g., Ecuador, Peru, Guyana, and Guatemala), whereas several Caribbean island nations have demonstrated significant increases.

As others have pointed out (e.g., Simpson, 1983). the retinal supply tends to come from vegetable sources in developing and often deficient areas. Since 1961-63. 83% to 84% of the retinal came from fruits and vegetable products. the rest from meat and animal products, in developing areas (Table 1). Only 48% to 49% of the retinol was from fruits and vegetables in developed areas (FAO, 1988). Thus, increased intake of provitamin A carotenes from available horticultural crops could play a significant role in reducing the incidence of world vitamin A deficiency. Increased carotene intake also could reduce the risk of cancer in both developed and developing areas.

Sources of provitamin A carotenes

Provitamin A carotenes account for the yellow, orange. or red color in many vegetables and fruits (Table 2); they also occur with chlorophyll in all green plant tissues. Only plants synthesize carotenoids, and several different carotenoids always occur when they are present. Since many carotnoids are not vitamin A precursors. earlier values published for carotene content in fruits and vegetables tended to be inflated. With the development of high-performance liquid chromacographic methods for quantifying individual carotenes. more-accurate estimates of provitamin A capacity are able to be made and current estimates tend to be lower (Table 2) (Gebhardt et al.. 1982; Simpson. 1983; Haytowitz and Matthews, 1984). In contrast to this general trend. carotene values for carrot, sweetpotato. and squash arc higher than earlier values. since new darker-orange cultivars are now available (Putnam. 1989).

The fruits and vegetables listed in Table 2 represent only 3 small subset of those conraining carotenes. These were selected because they contain at least 1 ppm provitamin A carotenes and they are produced in high enough quantity to appear in FAO agricultural production statistics (e.g.. FAO. 1988). Also included for comparison are broccoli, parsley, spinach, and lettuce. It should be noted that, except for maize and sweetpotatoes, none of the widely grown crops that serve as major sources of dietary calories and protein (rice, wheat. potatoes, cassava sorghum, dry pulses, millet. yams) contain significant levels of provitamin A carotenes.

The availability of high-carorene horticultural crops is one indication of the horticultural contribution to world vitamin A status. Availability in developing counties is increasing for nearly all horticultural commodities that contain carotenes (Table 3).

One major exception to this trend is sweetpotatoes. for which per caput supply has decreased 29% in developing countries since 1961-65. Contrary to all other carotenecontaining commodities, sweetpotato-per-caput supply also has reduced dramatically in developed areas over this time (FAO, 1988). When orange-colored cultivars are grown in developing areas, sweetpotatoes have been a very important source of dietary retinol. The trend toward greater per-caput availability of retinol in Asia (Table 1) suggests that the increased availability of other provitamin A carotene sources is counteracting diminishing sweetpotato supply.

Caution must be exercised in drawing conclusion about vitamin A status from food availability since these statistics fail to consider consumption, absorption. and use, which may be confounded by fat intake, fever, diarrhea, and other factors. Vitamin A deficiency symptoms can occur even with adequate consumption of provitamin A-rich foods (Tarwotjo et al., 1982). Furthermore, availability may be a poor reflection of local consumption when crops are grown for export markets. Horticultural commodities often end up in local, national, or international markets to further confound estimates of intake based on supply.

In addition to sweetpotato, red palm oil is the other significant source of provitamin A carotenes in many developing areas. Although unavailable in developed nations, local differences in red palm oil consumption are well-correlated with the incidence of vitamm A deficiency in Africa (Carter and Cook. 1963; Thompson, 1965). Red palm oil availability has risen 7-fold per caput in Asia and 4-fold in all developing areas since 1961-65. Crude palm oil carotene content varies from 300 to 2560 ppm. but, unfortunately, from a nutritional standpoint, palm breeders select for low carotene concern so that palm oil can compete in a world market with otherwise colorless oils. Refuting processes further reduce carotene content (Hartley, 1988).

Increasing the supply of provitamin A carotenes with nontraditional crops and dark-green leafy vegetables

The availability of provitamin A-rich horticultural crops that were, in 1961-65. nontraditional. has increased in most developing areas (Table 3). Dietary diversification to include European and Western crops such as carrots and tomatoes in Africa and Asian diets, or carrots and the originally African palm oil in Central and South America diets, may have played an important role in increasing available carotene and retinol supplies. Thus, a case can be made for introducing or expanding the use of nontraditional crops to diversify and fortify diets. However. the introduction of new crops must be gradual to avoid social resistance. Furthermore, growing and postharvest storage conditions must be appropriate before these crops can be produced successfully.

The production of nontraditional crops can create an incentive for greater productivity, since these crops are often more profitable in the market. Unfortunately, market profitability can compete with the improvement of local nutritional status since profitable crops tend to be sold rather than consumed locally. However, this did not occur with Indonesian mango production. where children consumed

Table 1. Contribution of vegetable carotenoids to world vitamin A supply.

Region	1961–63	1969–71	1979–81	1984–86	Change (%)[z]
World	2807 (68)[y]	2975 (68)	3158 (69)	3384 (69)	+2.1
Africa	4039 (81)	4118 (81)	4090 (80)	4029 (80)	–0.2
North/Central America	2409 (47)	2442 (48)	2743 (52)	2864 (53)	+19
South America	1691 (50)	1782 (50)	1788 (46)	1963 (50)	+16
Asia	2760 (88)	2889 (87)	3134 (86)	3401 (86)	+23
Europe	3058 (47)	3513 (48)	3620 (46)	3949 (42)	+29
Oceania	2882 (40)	3232 (43)	3282 (46)	3708 (52)	+29
Soviet Union	2332 (46)	2615 (46)	2681 (45)	3007 (46)	+29
Developed countries	2774 (48)	3107 (48)	3248 (48)	3490 (49)	+26
Developing countries	2823 (84)	2921 (84)	3126 (84)	3348 (83)	+19

[z]Change in beta-carotene equivalent supply 1961-63 to 1984-86.
[y]Beta-carotene equivalent in micrograms per caput per day from vegetable sources (percent contri-bution to total retinol equivalent supply); from FAO (1988).