

Latin American food sources of carotenoids

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SUMMARY. Latin America has a wide variety of carotenogenic foods, notable for the diversity and high levels of carotenoids. A part of this natural wealth has been analyzed. Carrot, red palm oil and some cultivars of squash and pumpkin are sources of both β -carotene and α -carotene. β -carotene is the principal carotenoid of the palm fruits burití, tucumã and bocaiuva, other fruits such as loquat, marolo and West Indian cherry, and sweet potato. Buriti also has high amounts of α -carotene and γ -carotene. β -Cryptoxanthin is the major carotenoid in caja, nectarine, orange-fleshed papaya, orange, peach, tangerine and the tree tomato. Lycopene predominates in tomato, red-fleshed papaya, guava, pitanga and watermelon. Pitanga also has substantial amounts of β -cryptoxanthin, γ -carotene and rubixanthin. Zeaxanthin, principal carotenoid of corn, is also predominant only in piquí. δ -Carotene is the main carotenoid of the peach palm and ζ -carotene of passion fruit. Lutein and β -carotene, in high concentrations, are encountered in the numerous leafy vegetables of the region, as well as in other green vegetables and in some varieties of squash and pumpkin. Violaxanthin is the principal carotenoid of mango and mamey and is also found in appreciable amounts in green vegetables. Quantitative, in some cases also qualitative, differences exist among cultivars of the same food. Generally, carotenoids are in greater concentrations in the peel than in the pulp, increase considerably during ripening and are in higher levels in foods produced in hot places. Other Latin America indigenous carotenogenic foods must be investigated before they are supplanted by introduced crops, which are often poorer sources of carotenoids.

Key words: Carotenogenic foods, carotenoids, fruits, vegetables, root crops.

RESUMEN. Fuentes alimenticias latinoamericanas de carotenoides. América Latina posee una gran variedad de alimentos carotenogénicos, notables por la diversidad y altos niveles de carotenoides. Una parte de esta riqueza natural ya fue analizada. Zanahoria, aceite de palma roja y algunos cultivares de calabaza son fuentes tanto de β -caroteno como de α -caroteno. β -Caroteno es también el principal carotenoide de los frutos de palma burití, tucumã y bocaiuva, otros frutos como néspera, marolo y acerola, y la patata dulce. La β -criptoxantina es mayoritaria en cajá, nectarina, papaya anaranjada, naranja, melocotón, mandarina y tamarillo. El licopeno predomina en tomate, papaya roja, guayaba, pitanga y sandía. En la pitanga se encuentran también cantidades substanciales de β -criptoxantina, γ -caroteno y rubixantina. La zeaxantina, principal carotenoide del maíz, es mayoritaria también solamente en piquí. El δ -caroteno es el carotenoide preponderante de la pupuña y el ζ -caroteno del maracujá. Luteína y β -caroteno, en altas concentraciones, están presentes en las numerosas hojas de la región, como en otras verduras y ciertas variedades de calabaza. La violaxantina es el carotenoide predominante del mango y mamey, pero está también en verduras en cantidades apreciables. Existen diferencias cuantitativas y, a veces cualitativas, entre cultivares del mismo alimento. Generalmente, los carotenoides se encuentran en niveles mayores en la cáscara en vez de la pulpa, aumentan considerablemente durante la maduración y son mayores en alimentos producidos en los lugares más calientes. Otras fuentes alimenticias indígenas de la América Latina deben ser investigadas, antes que sean substituidos por cultivos introducidos, que son frecuentemente fuentes más pobres de carotenoides.

Palabras clave: Alimentos carotenogénicos, carotenoides, frutos, verduras, vegetales.

INTRODUCTION

With its tropical and sub-tropical areas, Latin America abounds in carotenogenic plant foods. Aside from internationally recognized food sources of carotenoids, there is a remarkable variety of lesser known or virtually unknown carotenoid-containing species. A part of this rich natural resource has been analyzed, particularly in Brazil. This Brazilian endeavor has generated one of the world's most extensive databases on food carotenoids, but because of the diversity of sources, there is an urgent need to extend analytical activities as the first step to better utilization of valuable but

underexploited plant species. Because efforts along this line has been long in coming, a serious threat is the disappearance of carotenoid-rich indigenous species, supplanted by introduced crops, which are often poorer sources.

Fruits

The carotenoid composition of fruits is complex and variable (Table 1). Palm fruits, such as bocaiuva, burití, tucumã and peach palm (pupunha), are rich in carotenes (i.e. hydrocarbon carotenoids). Buriti has the highest β -carotene content of the foods already analyzed. Augmented by high levels of α -carotene and γ -carotene, which are also precursors

of vitamin A, this palm fruit presents a vitamin A value of about 6,500 RE (μg)/100 g. β -Carotene also predominates in bocaiúva and tucumã, while the vitamin A-inactive δ -carotene prevails in peach palm, although it also contains good amounts of β -carotene and γ -carotene. Bocaiúva comes from Mato

Grosso do Sul and the other three palm fruits are harvested from wild trees, especially in Northern Brazil. Given their carotenoid content, their commercial production should be encouraged.

TABLE 1
Carotenoid composition ($\mu\text{g/g}$) of fruits

Fruit	Portion Analyzed	Origin	N	Carotenoids
Bocaiúva (<i>Acronomia makayába</i>)	pulp	MS	5	β -carotene (59 ± 11), γ -carotene (0.9 ± 0.2), β -cryptoxanthin (1.7 ± 0.4), <i>cis</i> -lycopene (4.4 ± 0.3), <i>cis</i> -flavoxanthin (0.2 ± 0.1)
Buriti (<i>Mauritia vinifera</i> Mart)	pulp	PI	5	13- <i>cis</i> - α -carotene (1.5 ± 1.4), α -carotene (80 ± 9), 13- <i>cis</i> - β -carotene (3.8 ± 2.9), β -carotene (360 ± 32), 9- <i>cis</i> - β -carotene (0.7 ± 0.5), ζ -carotene (4.6 ± 0.5), β -zeacarotene (5.4 ± 1.5), γ -carotene (36 ± 4), zeaxanthin (20 ± 4)
Cajá (<i>Spondias lutea</i>)	pulp + peel	PE	4	α -carotene (0.9 ± 0.4), β -carotene (1.6 ± 0.2), ζ -carotene (0.3 ± 0.1), zeinoxanthin (4.3 ± 0.6), β -cryptoxanthin (16 ± 2), cryptoflavin (1.8 ± 0.7), lutein (0.4 ± 0.3)
	pulp	PE	1	α -carotene (2.1), β -carotene (2.6), zeinoxanthin (1.7), β -cryptoxanthin (8.3), cryptoflavin (0.6), lutein (2.0)
Cashew-apple (<i>Anacardium occidentale</i>) yellow type	whole fruit	SP,CE	2	α -carotene (0.1), β -carotene (0.6), ζ -carotene (tr), <i>cis</i> - β -carotene (0.3), β -cryptoxanthin (0.5), aurochrome (tr), cryptochrome (tr), auroxanthin (tr)
	red type	SP,PA	2	α -carotene (0.2), β -carotene (1.7), ζ -carotene (tr), <i>cis</i> - β -carotene (0.5), β -cryptoxanthin (1.1), aurochrome (tr), cryptochrome (tr), auroxanthin (tr)
Guava (<i>Psidium guajava</i>) Cultivar IAC-4	whole fruit	SP	4	β -carotene (3.7 ± 0.7), ζ -carotene (tr), γ -carotene (tr), zeinoxanthin (1.0 ± 0.6), lycopene (53 ± 6), β -carotene-5,6,5',6'-diepoxide (tr), trihydroxy- β -carotene-5,8-epoxide (4.0 ± 0.3)
	peeled fruit	SP	2	β -carotene (5.0 ± 1.2), ζ -carotene (tr), zeinoxanthin (0.5 ± 0.1), lycopene (57 ± 6), β -carotene-5,6,5',6'-diepoxide (0.1 ± 0.2), trihydroxy- β -carotene-5,8-epoxide (2.0 ± 0.2)
Undefined variety	whole fruit	PE	3	β -carotene (12 ± 5), γ -carotene (tr), <i>cis</i> - γ -carotene (tr), γ -carotene (0.4 ± 0.3), zeinoxanthin (1.9 ± 0.7), lycopene (53 ± 14), β -carotene-5,6,5',6'-diepoxide (0.1 ± 0.1), zeinoxanthin-5,8-epoxide (0.2 ± 0.1), trihydroxy-5,8-epoxy- β -carotene (2.1 ± 1.9)
Undefined variety	whole fruit	CE	2	β -carotene (5.5 ± 2.3), ζ -carotene (tr), γ -carotene (tr), zeinoxanthin (1.5 ± 0.2), lycopene (47 ± 16), β -carotene-5,6,5',6'-diepoxide (0.3 ± 0.4), trihydroxy-5,8-epoxy- β -carotene (2.3 ± 0.7)
Loquat (<i>Eriobotrya japonica</i> Lindl.) Mizuho	pulp	SP	5	β -carotene (8.0 ± 0.6), ζ -carotene (0.1 ± 0.1), neurosporene (1.1 ± 0.3), β -cryptoxanthin (4.5 ± 0.5), β -cryptoxanthin-5,6-epoxide (0.6 ± 0.2), violaxanthin (1.6 ± 0.1), auroxanthin (0.9 ± 0.1), neoxanthin (0.8 ± 0.1)
Mamey (<i>Mammea americana</i>)	pulp	MA	13	13- <i>cis</i> - β -carotene (0.3 ± 0.2), β -carotene (15 ± 2), 9- <i>cis</i> - β -carotene (0.2 ± 0.2), ζ -carotene (1.1 ± 0.6), β -zeacarotene (0.5 ± 0.3), β -apo-10'-carotenal (4.8 ± 0.8), β -apo-8'-carotenol (12 ± 7), violaxanthin (20 ± 8), luteoxanthin (0.6 ± 0.4), auroxanthin (1.8 ± 0.6)
Mango (<i>Mangifera indica</i> L.) Keitt	ripe pulp	BA	3	β -carotene (15 ± 2), unidentified (0.2 ± 0.0), <i>cis</i> - β -cryptoxanthin (tr-0.1), β -cryptoxanthin (0.3 ± 0.0), zeaxanthin (0.8 ± 0.2), luteoxanthin isomers (3.8 ± 0.6), violaxanthin (21 ± 3), 9- <i>cis</i> -violaxanthin (10 ± 1), 13- <i>cis</i> -violaxanthin (1.4 ± 0.1), <i>cis</i> -neoxanthin (tr-0.2), neoxanthin (2.1 ± 1.3)
	mature-green pulp	SP	3	β -carotene (1.7 ± 0.3), unidentified (0.1 ± 0.0), <i>cis</i> - β -cryptoxanthin (tr), β -cryptoxanthin (nd-tr), zeaxanthin (0.3 ± 0.0), luteoxanthin isomers (1.0 ± 0.2), violaxanthin (5.4 ± 1.7), 9- <i>cis</i> -violaxanthin (1.7 ± 0.4), 13- <i>cis</i> -violaxanthin (0.3 ± 0.1), <i>cis</i> -neoxanthin (0.1 ± 0.0), neoxanthin (1.6 ± 0.6)
	ripe pulp	SP	3	β -carotene (6.7 ± 1.6), unidentified (0.2 ± 0.0), <i>cis</i> - β -cryptoxanthin (tr-0.1), β -cryptoxanthin (0.2 ± 0.0), zeaxanthin (0.8 ± 0.3), luteoxanthin isomers (2.7 ± 0.2), violaxanthin (18 ± 4), 9- <i>cis</i> -violaxanthin (7.2 ± 1.4), 13- <i>cis</i> -violaxanthin (nd-tr), <i>cis</i> -neoxanthin (0.3 ± 0.2), neoxanthin (1.9 ± 0.9)

Tommy Atkins	mature-green pulp	SP	3	β -carotene (2.0±0.8), unidentified (nd-tr), <i>cis</i> - β -cryptoxanthin (0.1±0.0), β -cryptoxanthin (0.1±0.0), zeaxanthin (0.3±0.1), luteoxanthin isomers (1.3±0.7), violaxanthin (6.9±3.0), 9- <i>cis</i> -violaxanthin (3.3±1.3), 13- <i>cis</i> -violaxanthin (0.5±0.2), <i>cis</i> -neoxanthin (nd-tr), neoxanthin (2.6±1.8)
	ripe pulp	SP	3	β -carotene (5.8±2.5), <i>cis</i> - β -cryptoxanthin (0.1±0.1), β -cryptoxanthin (0.3±0.1), zeaxanthin (0.4±0.2), luteoxanthin isomers (2.0±0.6), violaxanthin (22±9), 9- <i>cis</i> -violaxanthin (14±5), 13- <i>cis</i> -violaxanthin (tr), <i>cis</i> -neoxanthin (1.0±1.0), neoxanthin (4.9±4.5)
Marolo (<i>Annona coriaceae</i>)	pulp	MG	5	α -carotene (0.6±0.2), β -carotene (7.0±4.0), ζ -carotene (0.1±0.0), β -zeacarotene (0.1±0.0), ϵ -carotene (0.1±0.0), β -cryptoxanthin (0.1±0.1), violaxanthin (0.1±0.1), lutein (0.7±0.2), mutatoxanthin (0.2±0.1)
Nectarine (<i>Prunus persica</i>)	pulp	SP	5	13- <i>cis</i> - β -carotene (0.1±0.1), β -carotene (1.0±0.2), 9- <i>cis</i> - β -carotene (0.1±0.1), ζ -carotene (0.2±0.1), <i>cis</i> - β -cryptoxanthin (0.3±0.2), β -cryptoxanthin (3.9±0.7), lutein (1.1±0.2), zeaxanthin (1.6±0.3), violaxanthin (0.8±0.1), auroxanthin (0.4±0.3)
Papaya (<i>Carica papaya</i>) Common	pulp	SP	5	β -carotene (1.2±0.9), ζ -carotene (0.8±0.5), β -zeacarotene (0.1±0.0), β -cryptoxanthin-5,6-epoxide (2.0±1.1), β -cryptoxanthin (8.1±1.7), cryptoflavin (0.8±0.3)
Solo	pulp	BA	5	β -carotene (2.5±1.0), ζ -carotene (1.4±0.8), γ -carotene (0.2±0.0), β -cryptoxanthin-5,6-epoxide (tr), β -cryptoxanthin (9.1±2.4), antheraxanthin (tr), lycopene (21±16)
Formosa	pulp	SP	5	β -carotene (1.4±0.5), ζ -carotene (1.7±0.6), β -cryptoxanthin-5,6-epoxide (3.8±1.3), β -cryptoxanthin (5.3±1.1), antheraxanthin (1.8±0.1), lycopene (19±4)
Formosa	pulp	BA	5	β -carotene (6.1±1.4), ζ -carotene (1.5±0.3), β -cryptoxanthin-5,6-epoxide (1.8±0.8), β -cryptoxanthin (8.6±2.2), antheraxanthin (3.3±0.4), lycopene (26±3)
Tailandia	pulp	BA	5	β -carotene (2.3±0.7), ζ -carotene (2.0±0.4), β -cryptoxanthin-5,6-epoxide (2.1±0.3), β -cryptoxanthin (9.7±1.8), antheraxanthin (4.0±2.9), lycopene (40±6)
Peach (<i>Prunus persica</i>) Rei da Conserva	pulp	SP	3	13- <i>cis</i> - β -carotene (0.2±0.1), β -carotene (1.1±0.4), 9- <i>cis</i> - β -carotene (0.1±0.0), ζ -carotene (0.4±0.2), <i>cis</i> - β -cryptoxanthin (1.0±0.5), β -cryptoxanthin (6.4±2.1), lutein (3.8±1.1), zeaxanthin (1.5±0.9), violaxanthin (0.8±0.6)
Diamante	pulp	SP	5	13- <i>cis</i> - β -carotene (0.2±0.1), β -carotene (0.6±0.2), 9- <i>cis</i> - β -carotene (0.1±0.1), ζ -carotene (0.2±0.1), <i>cis</i> - β -cryptoxanthin (0.2±0.1), β -cryptoxanthin (4.1±0.8), violaxanthin (0.9±0.4), luteoxanthin (0.7±0.3), auroxanthin (0.2±0.2)
Chilean*	pulp		5	13- <i>cis</i> - β -carotene (0.2±0.1), β -carotene (1.2±0.2), 9- <i>cis</i> - β -carotene (0.1±0.1), ζ -carotene (0.2±0.1), <i>cis</i> - β -cryptoxanthin (0.3±0.2), β -cryptoxanthin (5.1±1.5), lutein (2.2±0.4), zeaxanthin (0.2±0.2), violaxanthin (1.6±0.4), auroxanthin (0.8±0.4)
Peach palm (<i>Bactris gasipaes</i>)	boiled pulp	AM	5	α -carotene (3.2±3.1), β -carotene (22±12), δ -carotene (25±9), γ -carotene (18±7)
Piqui (<i>Cariocar vilosium</i>)	pulp	PI	5	α -carotene (0.1±0.1), β -carotene (1.2±0.5), ζ -carotene (0.5±0.3), <i>cis</i> - β -cryptoxanthin (0.4±0.2), β -cryptoxanthin (4.4±0.9), zeaxanthin (7.8±1.2)
Pitanga (<i>Eugenia uniflora</i>)	pulp	PE	18	phytofluene (13±2), β -carotene (9.5±2.1), ζ -carotene (4.7±1.6), unidentified (3.4±0.4), β -cryptoxanthin (47±2), γ -carotene (53±4), lycopene (73±1), rubixanthin (23±2)
Tree tomato (<i>Cyphomandra betacea</i>)	pulp	SP	5	β -carotene (7.9±3.6), ζ -carotene (tr), β -carotene-5,6-epoxide (0.3±0.1), β -cryptoxanthin (14±4), lutein (1.7±1.1), zeaxanthin (0.6±0.6)
Tucumã (<i>Astrocaryum vulgare</i>)	pulp	AM	5	β -carotene (107±31), β -zeacarotene (5.9±3.1), ζ -carotene (6.2±2.2), γ -carotene (2.0±1.6)
West Indian Cherry (<i>Malpighia glabra</i>)	pulp	SP	4	α -carotene (tr), β -carotene (4.0±0.6), β -cryptoxanthin (0.5±0.2)
		PE	18	α -carotene (0.1±0.1), β -carotene (26±4), β -cryptoxanthin (3.6±0.7)
		CE	4	α -carotene (tr), β -carotene (22±1), β -cryptoxanthin (2.1±0.4)

Unless stated otherwise, the carotenoids are in *trans*-form and the samples are ripe. N - number of sample lots analyzed; MS - Mato Grosso do Sul, PI - Piauí, PE - Pernambuco, SP - São Paulo, CE - Ceará, PA - Pará, MA - Maranhão, BA - Bahia, MG Minas Gerais, AM - Amazonas, nd - not detected, tr - trace.

*Only non-Brazilian sample analyzed.

References: Hiani and Penteado (1), Godoy and Rodriguez-Amaya (2-4), Rodriguez-Amaya and Kimura (5), Cecchi and Rodriguez-Amaya (6), Padula and Rodriguez-Amaya (7), Rodriguez-Amaya et al. (8,9), Mercadante et al. (10), Mercadante and Rodriguez-Amaya (11), Agostini et al. (12), Kimura et al. (13), Godoy et al. (14), Cavalcante and Rodriguez-Amaya (15).

Since lipids are known to stimulate absorption of carotenoids, palm fruit carotenoids may have the added advantage of greater bioavailability. The peach palm is only eaten cooked, and in this form, the provitamins A were found to be highly bioavailable in rats, more bioavailable than those of fresh mango (16). Buriti sweet made from the pulp was shown to be well-accepted and effective in the prevention of hypovitaminose A and treatment of xerophthalmia in children of the semiarid Northeastern region of Brazil (17).

β -carotene is also the main carotenoid of the non-palm fruits loquat, marolo and West Indian cherry (Table 1). Loquat and marolo are not rich sources of carotenoids, but loquat is available at the time of the year (May to October) when few carotenogenic fruits are available. West Indian cherry is a good source of β -carotene and it is well known and appreciated for its very high vitamin C content. Data obtained with this fruit clearly showed climatic effect. The fruits coming from the neighboring hot Northeastern states of Pernambuco and Ceará presented similar composition, with carotenoid levels pronouncedly higher than those of fruits produced in the temperate state of São Paulo.

β -Carotene has long been considered the predominating pigment of mango. However, a recent work (10,11) on Keitt and Tommy Atkins cultivars showed violaxanthin to be actually the major carotenoid (Table 1). Highly unstable, violaxanthin can be easily lost during analysis, and this probably led to its underestimation in earlier studies.

Mercadante and Rodriguez-Amaya (11) also demonstrated the increase in carotenogenesis, especially of the major carotenoids, in both Keitt and Tommy Atkins cultivars, as the fruits ripened from the mature-green stage (Table 1). This is an important point to consider since mangoes are consumed at the green stage (usually more immature than the mangoes analyzed in the study) in some countries. Moreover, climatic effects were evident with the Keitt mangoes, those produced in the hot Northeastern state of Bahia presenting distinctly higher carotenoid levels than those from São Paulo.

Mango is produced in considerable amounts in Latin America. Unfortunately, it is seasonal and the peak harvest coincides with that of many carotenogenic fruits.

Violaxanthin is also the main carotenoid of mamey. This fruit is notable for having appreciable amounts of an apocarotenal and an apocarotenol (Table 1).

The xanthophyll (i.e. oxygenated carotenoid) β -cryptoxanthin is the principal carotenoid of cajá, nectarine, orange-fleshed papaya, peach and the tree tomato. Peach and nectarine, together with apricot and plums, are apparently the only fruits produced in colder regions which contain appreciable amounts of carotenoids. The anthocyanin-colored fruits, such as apple, pear, prunes and grapes, are very low in carotenoids. Belonging to the same family, peach and nectarine have similar carotenoid composition (Table 1).

The data on cajá (Table 1) show that the carotenoids are more concentrated in the peel than in the pulp, as in most fruits

(18,19). Peeling cajá not only reduce the carotenoid concentration but also the amount of available edible material (8 g/fruit vs. 2g/fruit). Thus, peeling is not recommended when the peel is edible. An exception to this common pattern is the pink-fleshed guava in which β -carotene appeared slightly higher in the peeled fruit (Table 1) and lycopene is concentrated in the pulp.

Although native to Brazil, the tree tomato is hardly encountered in this country. It is better known and consumed in Ecuador. It is also found in Asian (e.g. New Zealand) and African (e.g. South Africa) countries.

Tangerine, orange and persimmons would also contain β -cryptoxanthin as the main carotenoids. Citrus fruits are being currently analyzed (20), a study which is long overdue, considering that Brazil is one of the world's major producers of oranges and production of this fruit far exceeds that of other fruits. Although a good part is exported, domestic consumption of orange is substantial.

The vitamin A-inactive but efficient antioxidant lycopene is the preponderant carotenoid of pink-fleshed guava, red-fleshed papaya and pitanga (Table 1). Aside from being a rich source of lycopene, guava is also high in vitamin C.

Papaya is available all year round at prices the population can afford and enjoys wide acceptability by both children and adults. Aside from qualitative and quantitative variation in the other carotenoids, cultivar differences is notable in lycopene, from not detected in the orange-fleshed common cultivar to a level twice as much in the Tailandia papaya, compared to the other red-fleshed papayas (Table 1).

Climatic or geographic effect is also demonstrated in the Formosa papaya. As compared to those from São Paulo, Formosa papaya from Bahia had higher β -carotene, β -cryptoxanthin and lycopene contents (Table 1).

Pitanga has an interesting carotenoid composition, with high levels of lycopene, rubixanthin (monohydroxy derivative of γ -carotene), β -cryptoxanthin and γ -carotene (Table 1). This fruit and West Indian cherry, both from Northeastern Brazil, have now been transformed from semi-cultivated to commercially produced fruits, with commercial production still expanding.

Piqui was considered for a long time as a very rich source of provitamin A. Analytical data did not confirm this belief. Piqui is low in carotenoids and the principal pigment is zeaxanthin (Table 1), which is vitamin A-inactive but is one of the two carotenoids implicated in the prevention of macular degeneration.

Cashew-apple is a poor source of carotenoids, but the cashew-apple juice is manufactured from the pseudofruit, a by-product of the cashew nut industry, thus turning what would otherwise be a waste product into a nutritious, aromatic juice. The vitamin C content is claimed to be several times higher than that of orange juice.

Passion fruit is also native to Brazil, and is now widely produced throughout the tropics. Brazilian production of this

fruit surpasses that of mango, guava and papaya; Brazil is the leading exporter of passion fruit juice. The carotenoid composition of this fruit is considered unusual because ζ -carotene is the principal carotenoid (21). The quantitative composition was not determined.

Other carotenogenic fruits, which are commercially produced and should be analyzed, are avocado, banana, melon, watermelon and pineapple. Banana is a poor source of carotenoids, but the amount of this fruit consumed by the population may increase its importance. It is, for example, the principal source of carotenoids in the Panamanian diet (22). There are still many indigenous fruits that await analyses.

Leafy vegetables

In contrast to fruits, leaves have a constant qualitative carotenoid pattern, the major carotenoids being lutein, β -carotene, violaxanthin and neoxanthin. α -Carotene, β - or α -cryptoxanthin, zeinoxanthin, antheraxanthin and lutein-5,6-epoxide can be encountered as minor constituents. Appreciable amount of lactucaxanthin is found in lettuce (23). Considerable quantitative differences occur among leaves.

The bioavailability of carotenoids from leaves is known to be lower than that of fruit carotenoids. On the other hand, the carotenoid contents of the former usually surpass those of the latter. Moreover, leaves are available all year round, easily produced in home gardens and are the most widely available and affordable sources of carotenoids worldwide.

Latin America has an enormous variety of wild, semi-cultivated and commercially produced leafy vegetables. As in other developing regions of the world, the tropical climate promotes the growth of green leafy spontaneous plants such as *Anaranthus spp.*, *Hibiscus spp.* and *Basella spp.*, which, in many cases, have higher overall food value than introduced vegetable species.

In Campinas, São Paulo, the β -carotene concentrations of common commercial leaves were determined in 5 to 15 sample lots for each leaf collected at different times during the year (24). The results in $\mu\text{g/g}$ were: parsley (*Petroselinum hortense*), 50 ± 15 ; roquette (*Eruca sativa*), 35 ± 13 ; coriander leaves (*Coriandrum sativum*), 47 ± 5 ; cress (*Nastrutium officinale*), 42 ± 10 ; kale (*Brassica oleracea* var. *acephala*), 35 ± 13 ; common chicory (*Chicorium intybus*), 34 ± 10 ; endive (*Chicorium endivia*), 17 ± 6 ; curly, unheaded lettuce (*Lactuca sativa*), 14 ± 5 ; Boston lettuce, 13 ± 5 ; cabbage (*Brassica oleracea* var. *capitata*), 0.8 ± 0.7 ; Chinese cabbage (*Brassica chinensis*), 1.0 ± 1.4 . Although the β -carotene values were reliable, those of lutein, which were also determined, were considerably underestimated in this study because of the saponification step. This work was undertaken before saponification was evaluated in detail (25). Thirteen sample lots each of mustard leaves (*Brassica juncea*), Swiss chard (*Beta vulgaris*) and taioba (*Xanthosoma spp.*) from the city of São Paulo were also analyzed and found to have β -carotene levels of 60 ± 15 , 13 ± 11 and $66 \pm 14 \mu\text{g/g}$, respectively (26). New Zealand spinach

(*Spinacea oleracea*) (5 sample lots) had $25 \pm 4 \mu\text{g/g}$ of *trans*- β -carotene (27).

The β -carotene concentrations of the mature leaves of lettuce ($12 \mu\text{g/g}$) and endive ($14 \mu\text{g/g}$) were 3 times greater than those of the young leaves (3.5 and $4.2 \mu\text{g}$, respectively), taken from the same bunches of leafy vegetables (24). The internal leaves had $0.38 \pm 0.01 \mu\text{g/g}$ β -carotene as compared to $16 \pm 2 \mu\text{g/g}$ in external leaves in 10 samples of cabbage (28).

The β -carotene contents of edible leaves from the state of Pará, Northern Brazil were also determined, one sample lot being analyzed in December and, for some samples, another sample lot in May (29). For endive, one sample lot was analyzed in May. The β -carotene levels ($\mu\text{g/g}$) were: beldroega (*Portulaca holimoides*), 27; bertalha (*Basella rubra*), 55; cariru (*Talinum sp.*), 12 and 30; endive (*Chicorium intybus*), 25; Swiss chard (*Beta vulgaris*), 49; African spinach (*Amaranthus sp.*), 39; Indian spinach (*Amaranthus sp.*), 47 and 79; jambu branco (*Spilanthes acmella*), 39; cassava (*Manihot esculenta*), 151 and 108; mentruz (*Chenopodium ambrosioides*), 49 and 60; orelha de macaco (*Alternanthera sp.*), 33 and 59; tomato (*Lycopersicum esculentum*), 55; vinageria branca (*Hibiscus sabdariffa*), 71 and 102; vinageria roxa (*Hibiscus acetosila*), 73 and 84. These leaves have comparatively higher β -carotene concentrations than the internationally known, commercially produced leafy vegetables in São Paulo.

The only published Latin American paper which presented quantitative data of the principal carotenoids of leaves is shown in Table 2, referring to five wild or semi-cultivated indigenous leaves. Except for beldroega, these leaves had higher β -carotene levels than parsley, which presented the highest β -carotene content among the commercially produced leaves of Campinas. Even beldroega, which had the lowest β -carotene level among the native leaves, surpassed four of the commercial vegetables. Beldroega is more widely consumed in Mexico than in Brazil.

Cultivar difference, seasonal variation and effect of farming practice on the carotenoid composition were studied in mature kale leaves taken from commercial farms (31). Carotenoid levels were higher in the cultivar Tronchuda in the summer, but no statistically significant difference was seen between Tronchuda and Manteiga cultivars in the winter. The β -carotene, lutein-violaxanthin and total carotenoid contents were higher in the winter than in the summer for the cultivar Manteiga. On the other hand, neoxanthin was higher in the summer for the Tronchuda kale. All constituent carotenoids were higher in samples from a "natural" farm as compared to those from a neighboring farm that used agrochemicals.

The edible leaves of carrots, which would usually be discarded, was found to have $2.1 \pm 1.0 \mu\text{g/g}$ of α -carotene and $27 \pm 11 \mu\text{g/g}$ of β -carotene in the cultivar Brasília and $8.0 \pm 5.4 \mu\text{g/g}$ of α -carotene and $20 \pm 9 \mu\text{g/g}$ of β -carotene in the cultivar Beta 3 (32).

TABLE 2
Carotenoid composition ($\mu\text{g/g}$)* of native leafy vegetables

Vegetable	β -Carotene	α -Cryptoxanthin	Lutein + violaxanthin	Zeaxanthin	Neoxanthin
Beldroega (<i>Portulaca oleracea</i>)	30 \pm 8	0.6 \pm 0.8	48 \pm 8	0.7 \pm 1.5	9 \pm 2
Caruru (<i>Amaranthus viridis</i>)	110 \pm 6	1.3 \pm 1.2	237 \pm 50	8.2 \pm 6.5	43 \pm 5
Mentruz (<i>Lepidium pseudodidymum</i>)	85 \pm 19	nd	164 \pm 32	1.0 \pm 2.1	36 \pm 6
Serralha (<i>Sonchus oleraceus</i>)	63 \pm 14	0.3 \pm 0.6	145 \pm 52	3.1 \pm 5.7	29 \pm 6
Taiobá (<i>Xanthosoma spp.</i>)	67 \pm 21	1.0 \pm 1.4	172 \pm 38	2.7 \pm 6.0	40 \pm 10

*Means and standard deviations of five sample lots collected at different times during the year, nd - not detected.
Reference: Mercadante and Rodriguez-Amaya (30).

A very promising leaf is the chaya (*Cnidoscolus aconitifolius*), which is native to Mexico and Central America. It is consumed boiled to eliminate toxic substances. The shrub requires very little care and produces a large quantity of leaves for many years. The chaya leaf has been the object of investigations in Guatemala and was found to have 150 $\mu\text{g/g}$ of β -carotene, higher than in many other leaves (33).

Fruit vegetables

Squashes and pumpkins are easy to produce, widely available all year round and are rich in carotenoids. Many different varieties of these fruit vegetable can be found in Latin America and the rest of the world.

Aside from varietal differences, substantial variations in the carotenoid concentrations of the same variety of squash or pumpkin can be noted in Table 3. The magnitude of variation is so much greater than that observed in other fruits and vegetables that the ranges, rather the means and standard deviations, are presented in the table. This can be attributed to the long period during which the Cucurbita fruits can be harvested at varying degrees of maturity. Also, while other fruits and vegetables need to be consumed within a limited period after harvest, intact squashes and pumpkins have a very long shelf-life, during which the biochemical processes continue. No attempt was made to choose samples according to exact maturity stages or time after harvest so as to reflect the type of variation consumers would be exposed to.

β -Carotene predominates in *C. moschata* Menina Verde (mature) and Baianinha and lutein in *C. maxima* Jerimum Caboclo. *C. maxima* Exposição and the hybrid Tetsukabuto have nearly the same amounts of these two carotenoids.

Cucurbita moschata Baianinha from Northeastern Brazil is notably rich in carotenoids. The hybrid Tetsukabuto, which is grown from imported seeds, has about the same carotenoid content as *C. maxima* Exposição, lower than those of the other

three *Curcubita* fruits. Many other *Curcubita* varieties in Brazil and other Latin American countries have not been analyzed.

Red, green, yellow and orange varieties of pepper are marketed in Latin America. In Mexico, where consumption of pepper is so much a part of tradition and culture, the provitamin A carotenoids of five cultivars (Verde, Serrano, Jalapeño, Poblano and Caribe) of immature peppers were determined (38). β -Carotene ranged from 1.7 to 6.0 $\mu\text{g/g}$, α -carotene from 0.17 to 1.1 $\mu\text{g/g}$, and β -cryptoxanthin from not detected to 0.07 $\mu\text{g/g}$.

In yellow pepper from São Paulo, lutein is the principal carotenoid of Zarco Hybrid F₁ and Sunboy Hybrid F₁ while β -cryptoxanthin-5,6,5',6'-diepoxide predominates in Amador Hybrid F₁ (Table 3).

Different varieties of tomato, the universal rich source of lycopene, is found throughout Latin America, although other sources of lycopene are also available. Guava, papaya cultivar Tailandia and pitanga (Table 1) were found to have higher lycopene content than the common Brazilian Santa Cruz tomato (Table 3). Other cultivars of tomato may have higher lycopene concentration.

Other non-leafy vegetables were analyzed for their provitamin A content (27). Except for broccoli flowerlets (β -carotene, 18 \pm 1), the other vegetables such as green beans, okra and Indian eggplant had low vitamin A value.

Root crops

Carotenes, particularly α - and β -carotene, generally predominate in the few carotenoid-containing roots. α -Carotene and β -carotene account for 80 to 90% of the total carotenoid content of carrot (*Daucus carota*). Carrot cultivars Nantes and Imperador produced in São Paulo have about 20 $\mu\text{g/g}$ of α -carotene and 35 $\mu\text{g/g}$ of β -carotene (27,39).

Cassava (*Manihot esculenta*) is a very popular food in Brazil and other Latin American countries. The cassava leaf is

TABLE 3
Carotenoid composition ($\mu\text{g/g}$) of fruit vegetables

Vegetable	Portion Analyzed	Origin	N	Carotenoids
Squash and Pumpkin (<i>Cucurbita maxima</i>) Exposição	pulp	SP	5	α -carotene (nd-0.2), β -carotene (3.1-28), <i>cis</i> - ζ -carotene (nd-0.6), mutatochrome (nd-0.4), α -cryptoxanthin (nd-3.5), β -cryptoxanthin (nd-0.8), cryptoflavin (nd-0.1), lutein (7.2-25), <i>cis</i> -lutein (nd-9.7), zeaxanthin (nd-9.7), taraxanthin (nd-3.6), violaxanthin (nd-26), <i>cis</i> -luteoxanthin (nd-0.9), trihidroxy- α -carotene (nd-1.0), neoxanthin (nd-4.2)
Jerimum Caboclo	pulp	PE	3	α -carotene (0.2-0.6), β -carotene (14-34), <i>cis</i> - β -carotene (1.5-2.7), α -cryptoxanthin (tr-6.7), α -cryptoxanthin-5,6-epoxide (nd-8.8), lutein (6.4-129), <i>cis</i> -lutein (nd-0.4), zeaxanthin (nd-0.2), taraxanthin (nd-6.0), <i>cis</i> -flavoxanthin (nd-6.0)
(<i>Cucurbita moschata</i>) Menina Verde	immature fruit	SP	5	α -carotene (tr-0.2), β -carotene (0.8-2.5), <i>cis</i> - β -carotene (nd-tr), mutatochrome (nd-0.1), α -cryptoxanthin (tr-0.5), α -cryptoxanthin-5,6-epoxide (nd-tr), lutein (0.7-7.4), <i>cis</i> -lutein (nd-0.4), taraxanthin (nd-1.2), violaxanthin (nd-0.3), <i>cis</i> -violaxanthin (nd-0.4), <i>cis</i> -antheraxanthin (nd-0.2), <i>cis</i> -luteoxanthin (nd-tr), neoxanthin (nd-tr)
	mature fruit	SP	5	α -carotene (8.3-42), β -carotene (14-79), <i>cis</i> - ζ -carotene (0.9-20), α -zeacarotene (nd-13), mutatochrome (nd-2.1), aurochrome (nd-0.3), δ -carotene (nd-0.6), γ -carotene (nd-tr), α -cryptoxanthin (tr-2.3), lutein (tr-6.4), <i>cis</i> -lutein (0.2-3.1), violaxanthin (nd-3.3), <i>cis</i> -violaxanthin (nd-2.4), <i>cis</i> -luteoxanthin (nd-tr)
Baianinha	pulp	BA	3	α -carotene (17-82), β -carotene (125-294), β -carotene-5,6-epoxide (nd-2.2), <i>cis</i> - β -carotene (4.9-30), α -zeacarotene (nd-1.7), neuroposrene (nd-tr), mutatochrome (nd-tr), δ -carotene (tr-0.7), α -cryptoxanthin (2.2-2.8), zeinoxanthin (tr-6.3), <i>cis</i> - β -cryptoxanthin-5,6,5',8'-diepoxide (nd-0.3), lutein (4.8-14), taraxanthin (nd-tr), <i>cis</i> -flavoxanthin (nd-0.7), <i>cis</i> -violaxanthin (tr-0.9), luteoxanthin (nd-0.9), <i>cis</i> -luteoxanthin (nd-0.5), auroxanthin (nd-0.3)
Hybrid Tetsukabuto	pulp	BA	3	α -carotene (nd-0.5), β -carotene (8.7-18), <i>cis</i> - β -carotene (nd-0.1), α -zeacarotene (nd-0.2), neuroposrene (nd-5.4), mutatochrome (nd-0.3), zeinoxanthin (0.6-10), β -cryptoxanthin (0.8-18), lutein (3.5-34), <i>cis</i> -lutein (nd-0.5), zeaxanthin (tr-6.5), taraxanthin (nd-8.5), flavoxanthin (nd-0.3), <i>cis</i> -violaxanthin (tr-2.7), luteoxanthin (nd-0.6), trihidroxy- α -carotene (nd-0.4), neoxanthin (nd-0.9)
Pepper (yellow) (<i>Capsicum annuum</i>) Amador Hybrid F ₁	fruit	SP	1*	α -carotene (1.3), β -carotene (2.2), <i>cis</i> - ζ -carotene (tr), unidentified (1.1), β -carotene-5,6,5',6'-diepoxide (3.9), β -cryptoxanthin-5,6,5',6'-diepoxide (12), β -cryptoxanthin (0.2), lutein (3.9), violaxanthin (4.0)
Zarco Hybrid F ₁	fruit	SP	1*	α -carotene (0.9), β -carotene (1.1), <i>cis</i> - ζ -carotene (tr), unidentified (1.0), β -carotene-5,6,5',6'-diepoxide (1.6), β -cryptoxanthin-5,6,5',6'-diepoxide (3.4), β -cryptoxanthin (tr), lutein (5.5), violaxanthin (2.2)
Sunboy Hybrid F ₁	fruit	SP	1*	α -carotene (0.5), β -carotene (1.2), <i>cis</i> - ζ -carotene (tr), unidentified (0.6), β -carotene-5,6,5',6'-diepoxide (1.6), β -cryptoxanthin-5,6,5',6'-diepoxide (2.5), β -cryptoxanthin (tr), lutein (4.1), violaxanthin (1.5)
Tomato (<i>Lycopersicon esculentum</i>) Santa Cruz	fruit	SP	10	<i>cis</i> -phytofluene (3.7 \pm 4.6), β -carotene (5.1 \pm 1.1), ζ -carotene (0.4 \pm 0.2), γ -carotene (0.7 \pm 0.2), <i>cis</i> -lycopene (3.0 \pm 2.4), lycopene (31 \pm 20)

Unless stated otherwise, the carotenoids are in *trans*-form and the samples are ripe.

N - number of sample lots analyzed; SP - São Paulo, PE - Pernambuco, BA - Bahia, nd - not detected, tr - trace.

*Values are means of 5 determinations of samples taken from the same sample lot.

References: Arima and Rodriguez-Amaya (34, 35), Bianchini and Penteadó (36), Tavares and Rodriguez-Amaya (37).

a rich source of β -carotene and lutein. The root, however, is low in carotenoids. Five cultivars of cassava (IAC 576-70, Ouro do Vale, Pioneira, IAC 289-70, Branca de Santa Catarina) produced in São Paulo had 0.1 to 0.6 $\mu\text{g/g}$ of *trans*- β -carotene (40).

Mandioquinha (*Arracacia xanthorrhiza*) also from São Paulo, had traces of α -carotene and 0.8 \pm 0.2 $\mu\text{g/g}$ of β -carotene (41).

Sweet potatoes, especially the yellow and orange varieties, are important sources of β -carotene worldwide. The leaves are

also consumed and should be good sources of β -carotene and lutein. In Brazil, however, sweet potato is not so popular and the varieties cultivated (usually white varieties) are not high in provitamin A. Table 4 shows the wide variation in the β -carotene content (not detected to 218 $\mu\text{g/g}$) of sweet potato cultivars. The American cultivars far surpassed the Brazilian varieties. Other Latin American countries cultivate colored varieties.

TABLE 4
Carotenoid composition ($\mu\text{g/g}$)* of sweet potatoes produced in Brazil

Cultivar	β -Carotene	β -Carotene -5,6-epoxide	β -Carotene 5,6,5',6'-epoxide	Luteochrome	α -Zeaxarotene	β -Zeaxarotene	Aurochrome
Monalisa	0.4 \pm 0.2	0.2 \pm 0.0	0.6 \pm 0.1	1.6 \pm 0.2	0.5 \pm 0.2	—	0.9 \pm 0.2
Centennial	149 \pm 1	8.3 \pm 0.0	4.6 \pm 0.5	1.5 \pm 0.7	—	3.4 \pm 0.7	2.6 \pm 0.1
Clone CNPH	4.9 \pm 0.2	0.6 \pm 0.3	1.2 \pm 0.7	2.9 \pm 0.4	0.6 \pm 0.1	—	—
Heart Gold	52 \pm 10	2.6 \pm 0.1	2.0 \pm 0.5	2.4 \pm 0.3	—	2.1 \pm 0.5	1.5 \pm 0.4
Anápolis	14 \pm 6	0.6 \pm 0.0	0.3 \pm 0.1	0.8 \pm 0.2	—	0.7 \pm 0.0	0.7 \pm 0.1
Acadian	218 \pm 34	5.8 \pm 1.7	3.0 \pm 1.5	4.9 \pm 0.1	—	2.2 \pm 0.2	1.7 \pm 0.1
Morada Inta	11 \pm 4	0.3 \pm 0.1	0.2 \pm 0.1	0.6 \pm 0.3	0.5 \pm 0.1	—	—
IAC-2-71	—	0.1 \pm 0.0	0.2 \pm 0.1	0.8 \pm 0.2	0.2 \pm 0.0	—	0.7 \pm 0.1
SRT-252	0.1 \pm 0.1	0.2 \pm 0.0	0.4 \pm 0.0	0.9 \pm 0.1	0.3 \pm 0.1	—	0.8 \pm 0.0
Vineland Bush	23 \pm 2	2.0 \pm 0.5	2.7 \pm 0.5	2.4 \pm 0.2	0.9 \pm 0.1	—	2.1 \pm 0.2

*Values are means and standard deviations of three determinations of samples taken from the same sample lot.
Reference: Almeida-Muradian and Penteadó (42).

Processed foods

To utilize seasonal crops efficiently at peak harvest, permit wider distribution of products and provide a year-round supply, food processing is undertaken. The major part of the tomato

crop, for example, is transformed into tomato puree, paste, ketchup and juice. Processed foods constitute a good part of the Latin American food market, and some of these foods had been analyzed (Table 5).

TABLE 5
Carotenoid composition ($\mu\text{g/g}$) of commercial processed foods

Product	Origin	N	Carotenoids
Cashew-apple juice, bottled Brand A	PE	3	α -carotene (tr), β -carotene (0.7 \pm 0.1), ζ -carotene (tr), <i>cis</i> - β -carotene (0.1 \pm 0.1), β -cryptoxanthin (0.5 \pm 0.0), aurochrome+cryptochrome+auroxanthin (0.6 \pm 0.1)
Brand B	CE	3	α -carotene (tr), β -carotene (0.7 \pm 0.1), ζ -carotene (tr), <i>cis</i> - β -carotene (0.1 \pm 0.0), β -cryptoxanthin (0.5 \pm 0.1), aurochrome+cryptochrome+auroxanthin (0.5 \pm 0.1)
Corn, canned	SP	3	13- <i>cis</i> - β -carotene (0.3 \pm 0.2), β -carotene (0.9 \pm 0.2), 9- <i>cis</i> - β -carotene (0.4 \pm 0.2), ζ -carotene (0.2 \pm 0.1), <i>cis</i> - β -cryptoxanthin (0.3 \pm 0.1), β -cryptoxanthin (1.9 \pm 0.5), lutein (1.6 \pm 1.4), zeaxanthin (9.8 \pm 2.1), mutatoxanthin (1.1 \pm 0.4)
Mango juice, bottled Brand A	SP	3	β -carotene (7.8 \pm 0.9), unidentified (0.1 \pm 0.0), β -cryptoxanthin (0.1 \pm 0.0), auroxanthin (3.8 \pm 1.1)
Brand B	SP	3	β -carotene (12 \pm 1), β -cryptoxanthin (0.3 \pm 0.0), auroxanthin (5.8 \pm 0.2)
Brand C	SP	3	β -carotene (6.3 \pm 1.3), β -cryptoxanthin (0.2 \pm 0.1), auroxanthin (6.4 \pm 4.3)
Passionfruit juice, bottled	PE	3	α -carotene (tr), β -carotene (1.1 \pm 0.1), ζ -carotene (3.6 \pm 0.8), <i>cis</i> -neurosporene (0.4 \pm 0.0), neurosporene (1.1 \pm 0.0), γ -carotene (tr), lycopene (tr), aurochrome (tr), cryptochrome (tr), auroxanthin (tr)
	CE	3	α -carotene (tr), β -carotene (2.3 \pm 0.0), ζ -carotene (6.3 \pm 0.4), <i>cis</i> -neurosporene (0.5 \pm 0.1), neurosporene (2.2 \pm 0.1), γ -carotene (tr), aurochrome (tr), cryptochrome (tr), auroxanthin (tr)
Peach, canned	SP	3	13- <i>cis</i> - β -carotene (0.2 \pm 0.0), β -carotene (1.0 \pm 0.3), 9- <i>cis</i> - β -carotene (0.2 \pm 0.1), ζ -carotene (0.1 \pm 0.1), <i>cis</i> - β -cryptoxanthin (0.5 \pm 0.1), β -cryptoxanthin (2.5 \pm 0.3), lutein (0.6 \pm 0.6), zeaxanthin (0.8 \pm 0.3), luteoxanthin (0.3 \pm 0.1)
Peach juice, bottled	SP	3	13- <i>cis</i> - β -carotene (0.2 \pm 0.0), β -carotene (0.9 \pm 0.2), 9- <i>cis</i> - β -carotene (0.2 \pm 0.1), ζ -carotene (0.2 \pm 0.1), <i>cis</i> - β -cryptoxanthin (0.3 \pm 0.1), β -cryptoxanthin (1.6 \pm 0.4), lutein (1.3 \pm 0.3), zeaxanthin (0.4 \pm 0.1), auroxanthin (0.8 \pm 0.5)
Tomato juice, bottled Brand A	SP	3	<i>cis</i> -phytofluene (5.1 \pm 1.4), 13- <i>cis</i> - β -carotene (0.02 \pm 0.01), β -carotene (2.0 \pm 0.5), ζ -carotene (1.3 \pm 0.3), <i>cis</i> -lycopene (7.1 \pm 5.5), <i>trans</i> -lycopene (62 \pm 8)
Tomato puree Brand A, cartoned	SP	3	<i>cis</i> -phytofluene (9.4 \pm 0.9), 13- <i>cis</i> - β -carotene (1.1 \pm 1.0), β -carotene (3.0 \pm 0.9), 9- <i>cis</i> - β -carotene (0.3 \pm 0.2), ζ -carotene (3.3 \pm 1.5), <i>cis</i> -lycopene (16 \pm 9), lycopene (133 \pm 8)
Brand A, bottled	SP	3	<i>cis</i> -phytofluene (14 \pm 1), 13- <i>cis</i> - β -carotene (1.0 \pm 0.5), β -carotene (4.3 \pm 1.4), ζ -carotene (2.2 \pm 0.2), <i>cis</i> -lycopene (14 \pm 12), lycopene (134 \pm 58)

Brand A, canned	SP	3	<i>cis</i> -phytofluene (14±9), 13- <i>cis</i> -β-carotene (2.1±1.5), β-carotene (4.4±2.5), 9- <i>cis</i> -β-carotene (0.5±0.4), ζ-carotene (3.2±2.7), <i>cis</i> -lycopene (5.6±2.4), lycopene (114±89)
Brand B, cartoned	SP	3	<i>cis</i> -phytofluene (11±1), 13- <i>cis</i> -β-carotene (1.8±0.7), β-carotene (5.0±1.1), 9- <i>cis</i> -β-carotene (0.6±0.1), ζ-carotene (2.6±1.1), <i>cis</i> -lycopene (3.6±2.0), lycopene (88±43)
Brand B, bottled	SP	3	<i>cis</i> -phytofluene (12±2), 13- <i>cis</i> -β-carotene (1.3±1.1), β-carotene (6.2±1.4), 9- <i>cis</i> -β-carotene (0.4±0.2), ζ-carotene (3.3±0.7), <i>cis</i> -lycopene (5.6±1.3), lycopene (194±81)
Brand B, canned	SP	3	<i>cis</i> -phytofluene (11±4), 13- <i>cis</i> -β-carotene (1.2±0.1), β-carotene (3.9±1.0), 9- <i>cis</i> -β-carotene (0.5±0.1), ζ-carotene (1.4±0.2), <i>cis</i> -lycopene (18±4), lycopene (74±18)
Tomato paste Brand A, bottled	SP	3	<i>cis</i> -phytofluene (10±3), 13- <i>cis</i> -β-carotene (1.9±0.9), β-carotene (8.7±3.2), 9- <i>cis</i> -β-carotene (0.2±0.3), ζ-carotene (4.3±1.4), <i>cis</i> -lycopene (31±22), lycopene (170±61)
Brand A, canned	SP	3	<i>cis</i> -phytofluene (17±2), 13- <i>cis</i> -β-carotene (2.0±1.8), β-carotene (6.6±1.3), ζ-carotene (5.0±1.1), <i>cis</i> -lycopene (21±8), lycopene (164±53)
Brand B, bottled	SP	3	<i>cis</i> -phytofluene (9.2±2.8), 13- <i>cis</i> -β-carotene (1.2±0.3), β-carotene (5.9±1.0), 9- <i>cis</i> -β-carotene (0.5±0.2), ζ-carotene (2.5±0.7), <i>cis</i> -lycopene (8.3±3.4), lycopene (158±22)
Brand B, canned	SP	3	<i>cis</i> -phytofluene (13±4), 13- <i>cis</i> -β-carotene (2.6±0.3), β-carotene (4.3±0.8), 9- <i>cis</i> -β-carotene (1.0±0.1), ζ-carotene (2.7±0.1), <i>cis</i> -lycopene (15±6), lycopene (183±23)
Ketchup Brand A	SP	3	<i>cis</i> -phytofluene (16±1), 13- <i>cis</i> -β-carotene (0.3±0.2), β-carotene (3.5±0.8), 9- <i>cis</i> -β-carotene (0.7±0.1), ζ-carotene (3.6±0.2), <i>cis</i> -lycopene (10±2), lycopene (103±41)
Brand B	SP	3	<i>cis</i> -phytofluene (8.5±0.6), 13- <i>cis</i> -β-carotene (0.5±0.1), β-carotene (3.5±0.6), 9- <i>cis</i> -β-carotene (0.5±0.1), ζ-carotene (1.5±0.6), <i>cis</i> -lycopene (6.3±5.6), lycopene (86±30)

Unless stated otherwise, the carotenoids are in *trans*-form. N - number of sample lots analyzed; PE - Pernambuco, CE - Ceará, SP - São Paulo, tr - trace. References: Cecchi and Rodriguez-Amaya (6, 43), Tavares and Rodriguez-Amaya (37, 44), Mercadante and Rodriguez-Amaya (11).

The carotenoid composition of processed foods would depend on the composition of the raw material and the processing conditions, which could lead to varying degrees of degradation of the unstable carotenoids. Thus, the carotenoid levels of processed foods are often lower than those of the raw materials, unless concentration is part of the process as in the manufacture of tomato puree and paste. For better retention of carotenoids, effective control of the raw material and the processing and storage conditions are warranted.

Palm oil

In recent years, renewed attention has been directed to red palm oil as a rich source of bioavailable provitamin A. In Brazil, red palm (*Elais guineensis*) production has expanded for other reasons - e.g. as raw material for fractioning oleins and stearins, producing natural fat with diverse applications in the food industry, without the use of hydrogenation. The carotenoid extract can be an important by-product. Oil extracted from the sterilized commercial cultivar Tenera had 64 μg/g 13-*cis*-α-carotene, 94 μg/g *trans*-α-carotene, 129 μg/g 13-*cis*-β-carotene, 229 μg/g *trans*-β-carotene and 53 μg/g 9-*cis*-β-carotene (45). This abundant carotenoid supply is unfortunately destroyed during refining of the oil. Recently, however, several countries are recovering the carotenoids during oil processing to serve as provitamin A source.

In the state of Bahia, crude red palm oil has been a common ingredient in local cuisine. As Bahian recipes become more popular in other parts of the country, so does red palm oil. Oil from other palm fruits can also be produced and serve as excellent sources of carotenoids.

With such a diversity of sources, Latin America has the daunting task of analyzing and utilizing these sources to

promote the health of the population. If successful, such an effort will certainly be very rewarding.

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