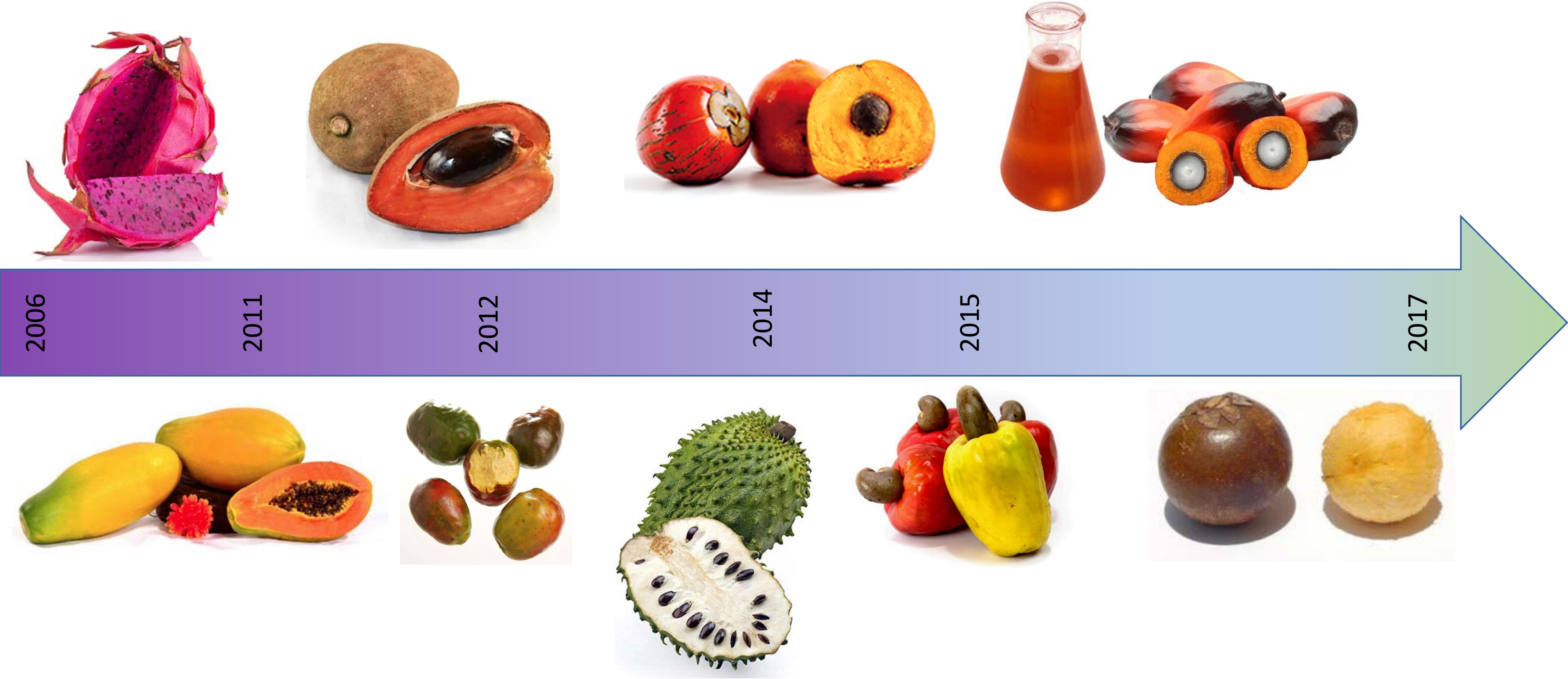
Latin American sources of carotenoids and polyphenols for nutritional and health improvement in developing countries

Dra. Patricia Esquivel

UNIVERSIDAD DE COSTA RICA

UNIVERSITÄT HOHENHEIM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PHYTOTHERAPY RESEARCH
Phytother. Res. **31**: 871–884 (2017)
Published online 2 May 2017 in Wiley Online Library
(wileyonlinelibrary.com) **DOI**: 10.1002/ptr.5819

REVIEW

C-Glycosyl Flavonoids from *Beta vulgaris Cicla* and Betalains from *Beta vulgaris rubra*: Antioxidant, Anticancer and Antiinflammatory Activities—A Review

Paolino Ninfali,* Elena Antonini, Alessandra Frati and Emanuele-Salvatore Scarpa
Department of Biomolecular Sciences, University of Urbino 'Carlo Bo', via Saffi, 261029, Urbino, PU, Italy

PLOS | ONE

RESEARCH ARTICLE

White Pitaya (*Hylocereus undatus*) Juice Attenuates Insulin Resistance and Hepatic Steatosis in Diet-Induced Obese Mice

Haizhao Song[1,2], Zihuan Zheng[1], Jianan Wu[1], Jia Lai[1], Qiang Chu[1], Xiaodong Zheng[1,2]*

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Phytother Res. 2015 Dec;29(12):1964-73. doi: 10.1002/ptr.5491. Epub 2015 Oct 14.

Betanin-Enriched Red Beetroot (Beta vulgaris L.) Extract Induces Apoptosis and Autophagic Cell Death in MCF-7 Cells.

Nowacki L[1,2], Vigneron P[2], Rotellini L[2], Cazzola H[1], Merlier F[1], Prost E[1], Ralanairina R[3], Gadonna JP[3], Rossi C[1], Vayssade M[2].

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Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Original article

The flesh ethanolic extract of *Hylocereus polyrhizus* exerts anti-inflammatory effects and prevents murine colitis

Dulce C. Macias-Ceja [a], Jesus Cosín-Roger [b], Dolores Ortiz-Masiá [c], Pedro Salvador [b], Carlos Hernández [a], Sara Calatayud [b], Juan V. Esplugues [a, b], Maria D. Barrachina [b, *]

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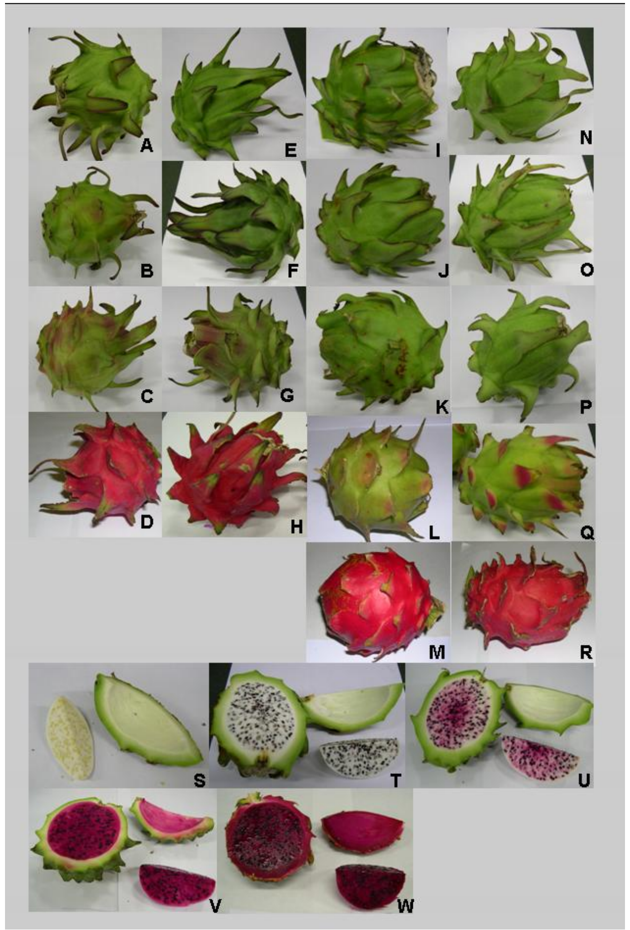
Comparison of morphological and chemical fruit traits from different pitaya genotypes (*Hylocereus* sp.) grown in Costa Rica (Esquivel et al., 2007)

Phenolic compound profiles and their corresponding antioxidant capacity in purple pitaya (*Hylocereus* sp.) genotypes (Esquivel et al., 2007)



Fruit characteristics during growth and ripening of different *Hylocereus* genotypes (Esquivel et al., 2007)

Pigment pattern and expression of colour in fruits from different *Hylocereus* sp. genotypes (Esquivel et al. 2007)

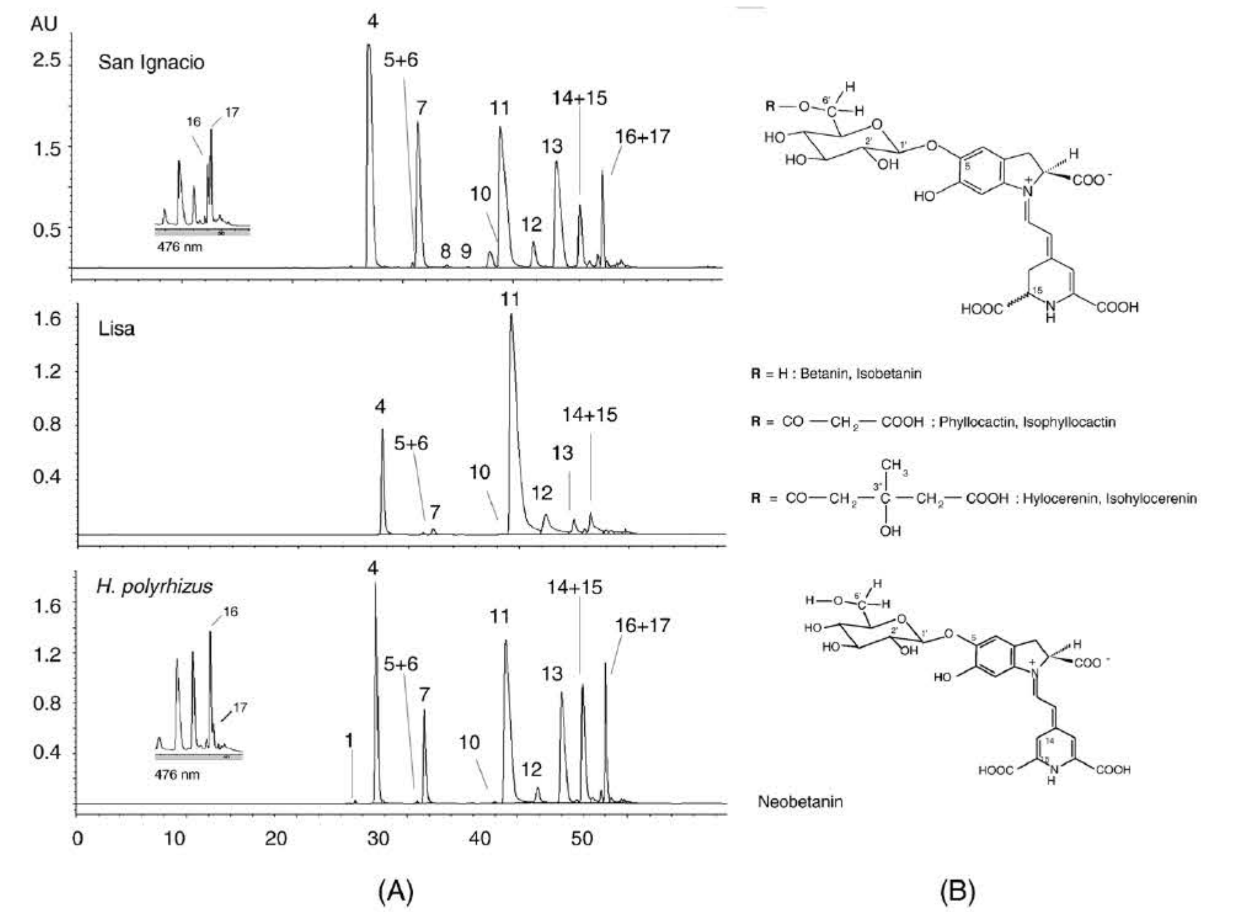


Fig. 1. (A) Representative betacyanin profiles from *Hylocereus* genotypes monitored at 538 nm. For peak assignment see Table 2. (B) Structures of the major betacyanins identified in the genotypes studied.

Neutral sugar profile of cell wall polysaccharides of pitaya (Hylocereus sp.) fruits (Ramirez-Truque et al., 2011)

Characterization of cell wall polysaccharides of purple pitaya (*Hylocereus* sp.) pericarp (Montoya et al. 2014)

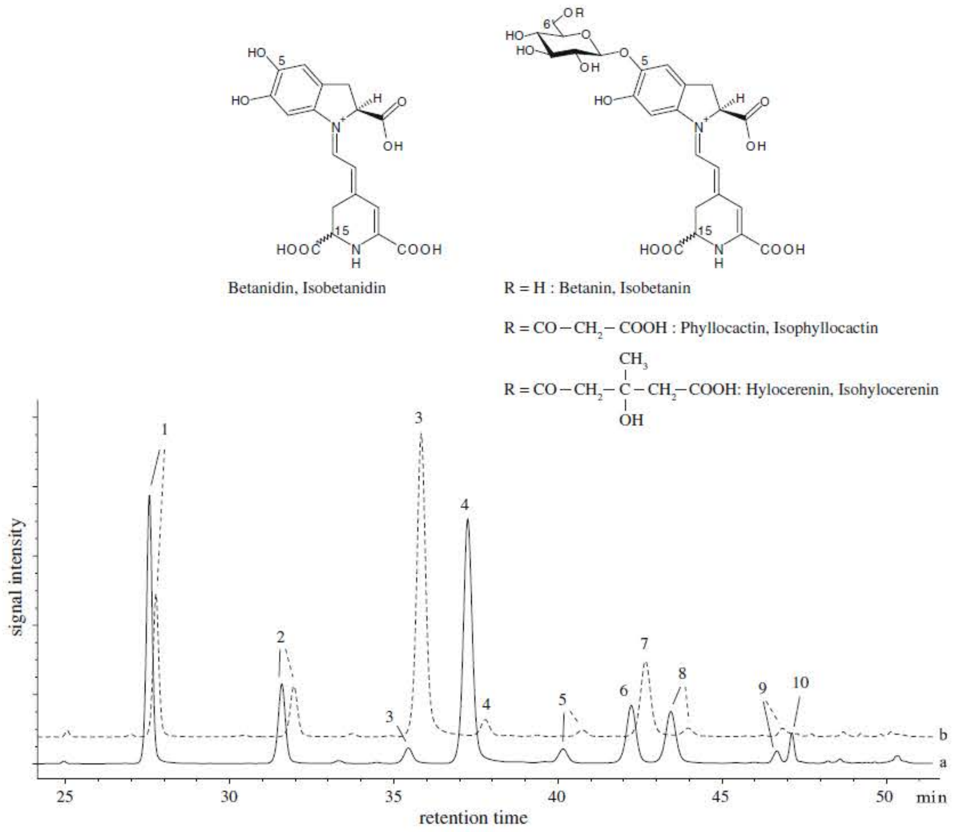
Chemical characterization of Central American pitaya (*Hylocereus* sp.) seeds and seed oil (Villalobos-Gutiérrez et al., 2012)

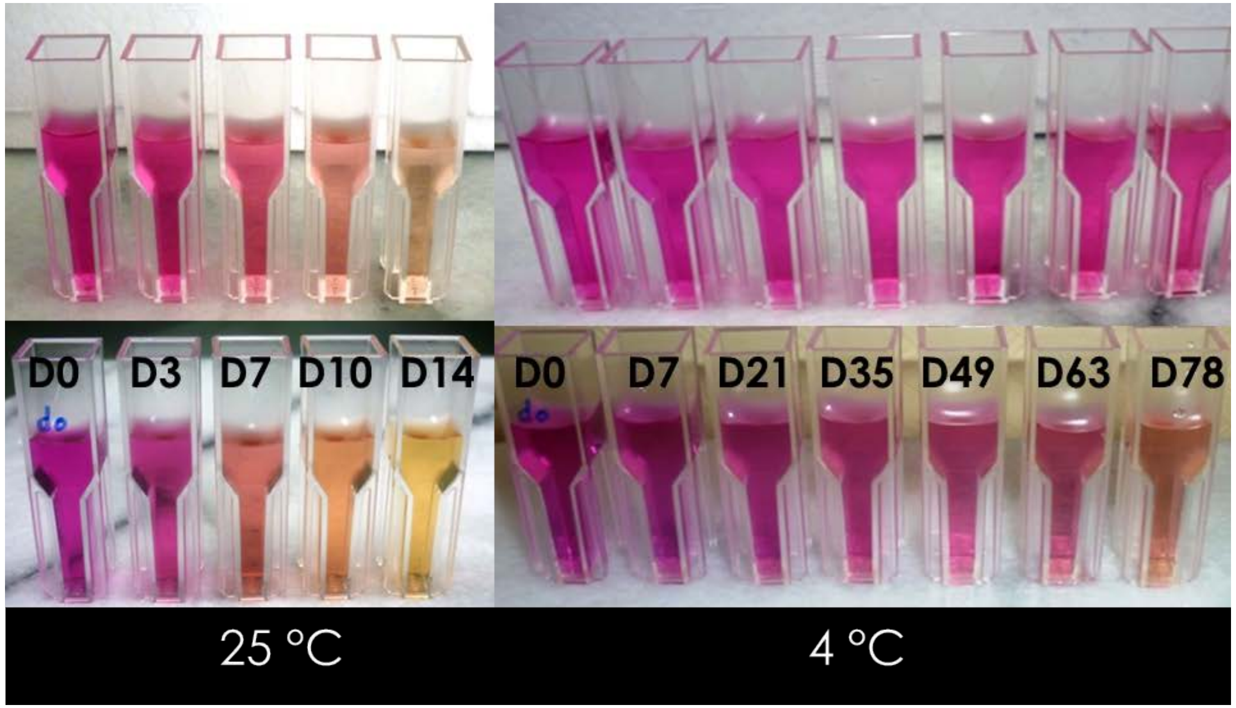
Figure 1. (a) Red pitaya fruit, (b) seeds and (c) seed extracted oil.

Figura 1. (a) Fruto de la pitaya roja, (b) semillas y (c) aceite extraído de las semillas.

Development and optimization of low temperature enzyme-assisted liquefaction for the production of colouring foodstuff from purple pitaya (*Hylocereus* sp. [Weber] Britton & Rose) (Schweiggert et al., 2009)

Fig. 1 HPLC separation of betalains of genuine pitaya pulp (**a**) and enzyme-assisted liquefied pitaya pulp (**b**) monitored at 538 nm. For peak assignment see Table 3

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D14
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D7
D21
D35
D49
D63
D78
25 °C
4 °C








Nutrient	Unit	1 Value per 100 g
Minerals		
Calcium, Ca	mg	20
Iron, Fe	mg	0.25
Magnesium, Mg	mg	21
Phosphorus, P	mg	10
Potassium, K	mg	182
Sodium, Na	mg	8
Zinc, Zn	mg	0.08
Vitamins		
Vitamin C, total ascorbic acid	mg	60.9
Thiamin	mg	0.023
Riboflavin	mg	0.027
Niacin	mg	0.357
Vitamin B-6	mg	0.038
Folate, DFE	µg	37
Vitamin B-12	µg	0.00
Vitamin A, RAE	µg	47
Vitamin A, IU	IU	950
Vitamin E (alpha-tocopherol)	mg	0.30
Vitamin D (D2 + D3)	µg	0.0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	2.6

USDA United States Department of Agriculture
Agricultural Research Service
National Nutrient Database for Standard Reference Release 28

One apple a day???

Nutrient	Unit	1 Value per 100 g
Minerals		
Calcium, Ca	mg	6
Iron, Fe	mg	0.12
Magnesium, Mg	mg	5
Phosphorus, P	mg	11
Potassium, K	mg	107
Sodium, Na	mg	1
Zinc, Zn	mg	0.04
Vitamins		
Vitamin C, total ascorbic acid	mg	4.6
Thiamin	mg	0.017
Riboflavin	mg	0.026
Niacin	mg	0.091
Vitamin B-6	mg	0.041
Folate, DFE	µg	3
Vitamin B-12	µg	0.00
Vitamin A, RAE	µg	3
Vitamin A, IU	IU	54
Vitamin E (alpha-tocopherol)	mg	0.18
Vitamin D (D2 + D3)	µg	0.0
Vitamin D	IU	0
Vitamin K (phylloquinone)	µg	2.2

Chemical and Morphological Characterization of Costa Rican Papaya (Carica papaya L.) Hybrids and Lines with Particular Focus on Their Genuine Carotenoid Profiles (Schweiggert et al., 2011)

Carotenogenesis and physico-chemical characteristics during maturation of red fleshed papaya fruit (Carica papaya L.) (Schweiggert et al., 2011)

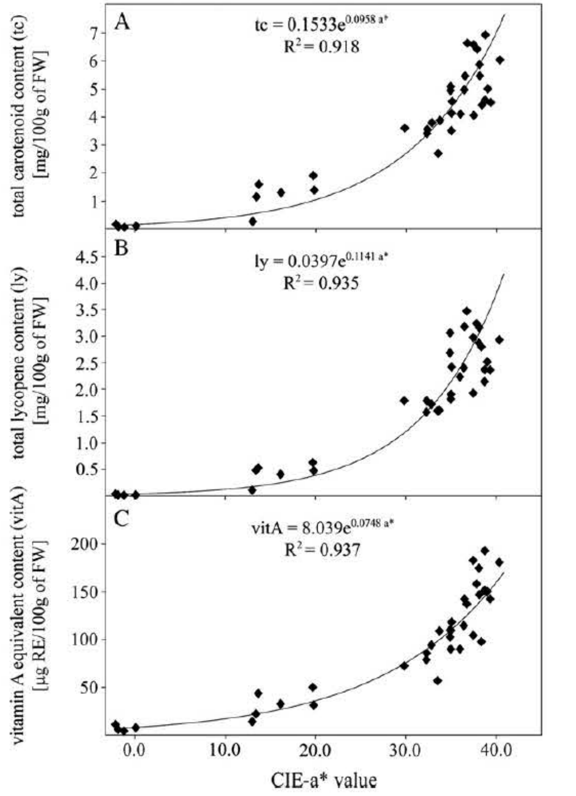
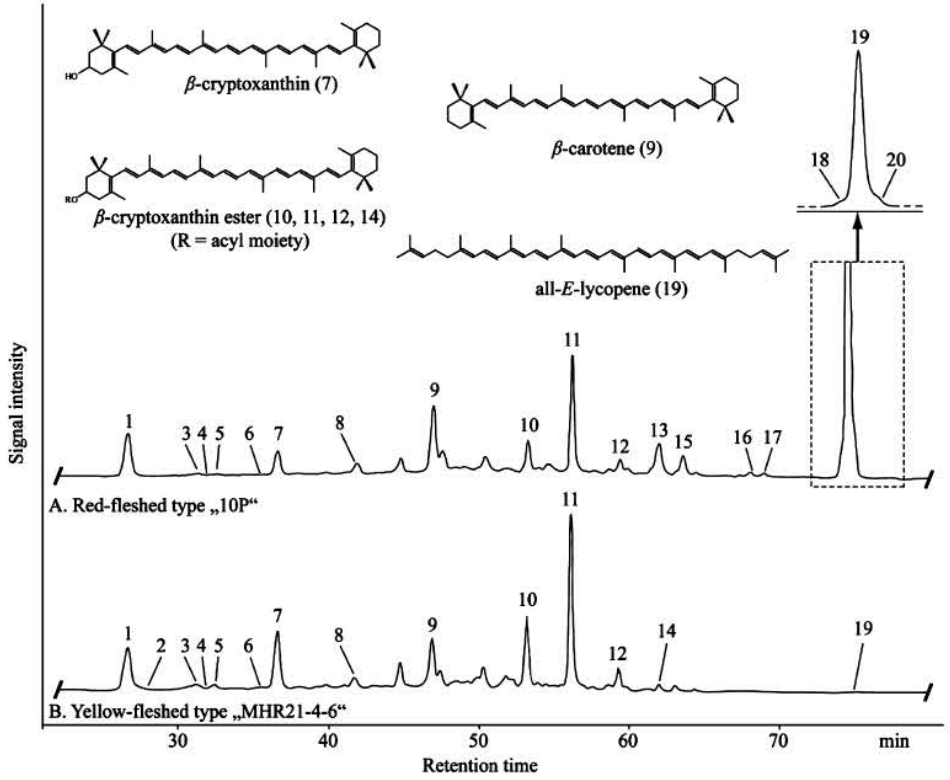
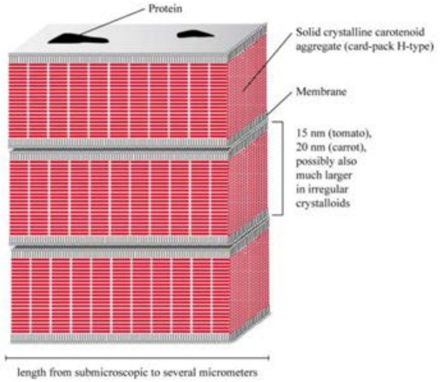


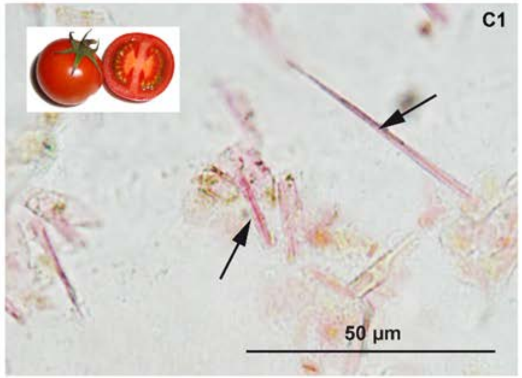
Fig. 5. Correlations of CIE-a* (pulp) and total carotenoid, total lycopene and vitamin A equivalent content.

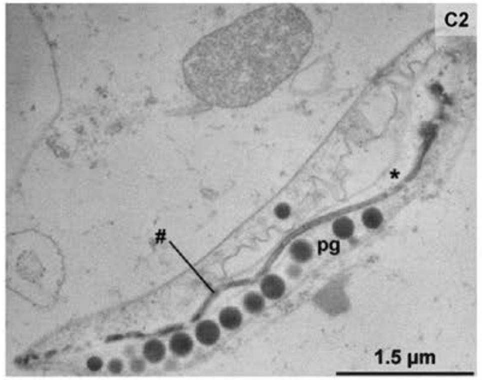


Characterization of chromoplasts and carotenoids of red- and yellow-fleshed papaya (*Carica papaya* L.) (Schweiggert et al., 2011)

Carotenoids are more bioavailable from papaya than from tomato and carrot in humans: a randomised cross-over study (Schweiggert et al., 2013)







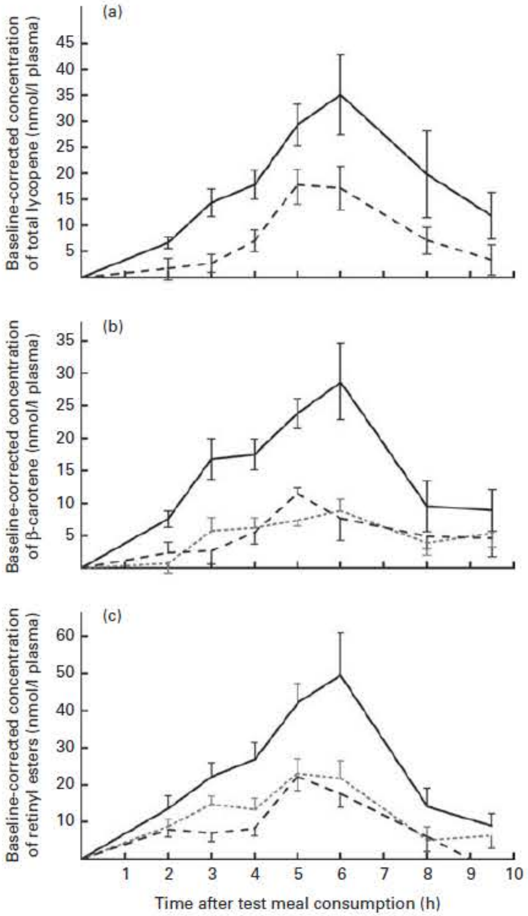
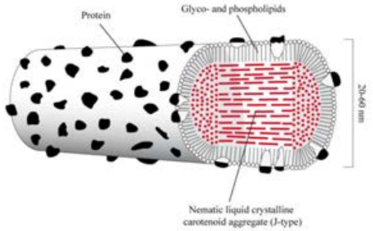
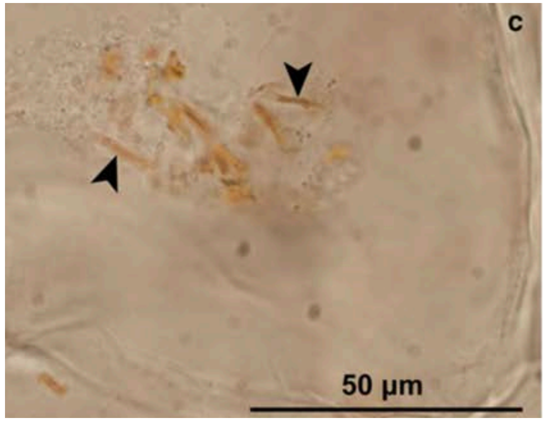
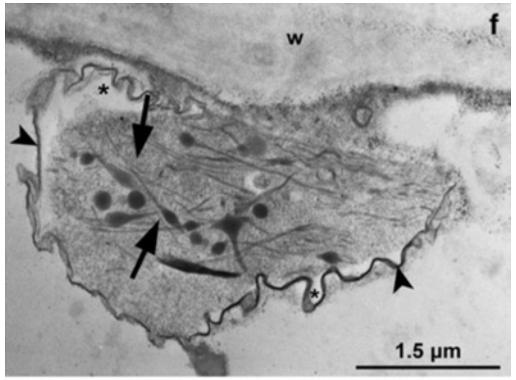
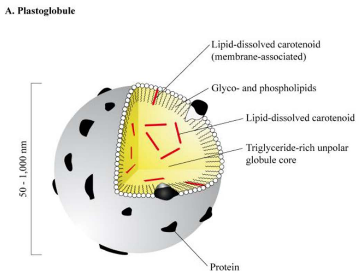


Fig. 1. Baseline-corrected plasma TAG-rich lipoprotein concentrations of (a) total lycopene, (b) β-carotene and (c) retinyl esters over 9·5 h after the consumption of the test meals. Values are means (*n* 16), with their standard errors represented by vertical bars. Mean value of the papaya test meal (—) was significantly higher than that of the carrot (----) or tomato (– –) test meal ($P \leq 0{\cdot}001$).









Schweiggert & Carle, 2017

THE OHIO STATE UNIVERSITY

Carotenoids and carotenoid esters of orange- and yellow fleshed mamey sapote (Pouteria sapota (Jacq.) H.E. Moore & Stearn) fruit and their postprandial absorption in humans (Chacon-Ordoñez et al., 2017)

Table 1
Photographs and CIE-L* C* h° color values of mamey sapote fruit mesocarp.

Genotype (Accession number)*	Mamey sapote fruit	CIE-L* C* h° color values		
		L*	C*	h°
8747		59.6 ± 2.5[b]	54.6 ± 3.0[a]	50.2 ± 2.1[b]
11129		59.1 ± 1.5[b]	48.1 ± 3.8[b]	52.2 ± 2.3[b]
11163		62.8 ± 1.8[a]	42.5 ± 2.2[c]	67.5 ± 5.8[a]

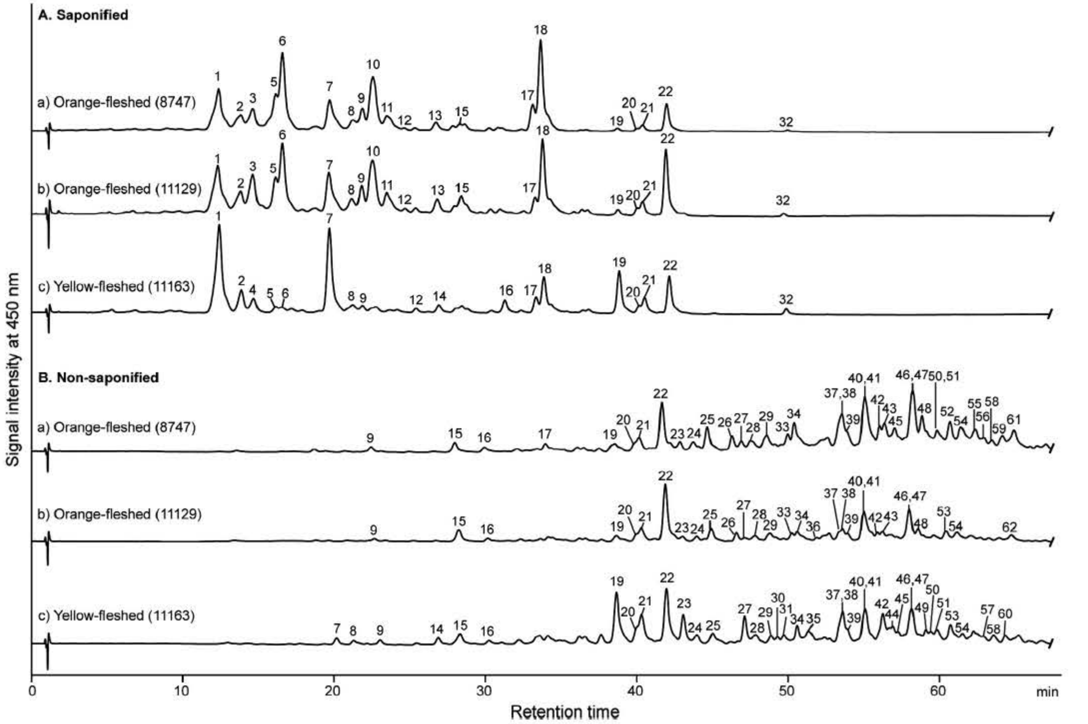


Fig. 1. HPLC-DAD separation of carotenoids in saponified (A) and non-saponified (B) extracts from different mamey sapote genotypes monitored at 450 nm. Chromatograms of two orange-fleshed genotypes, i.e., a) 8747 and b) 11129, and one yellow-fleshed genotype, i.e., c) 11163, are displayed. See Table 2 for peak assignment. Signal intensity of the different traces are in the same scale.

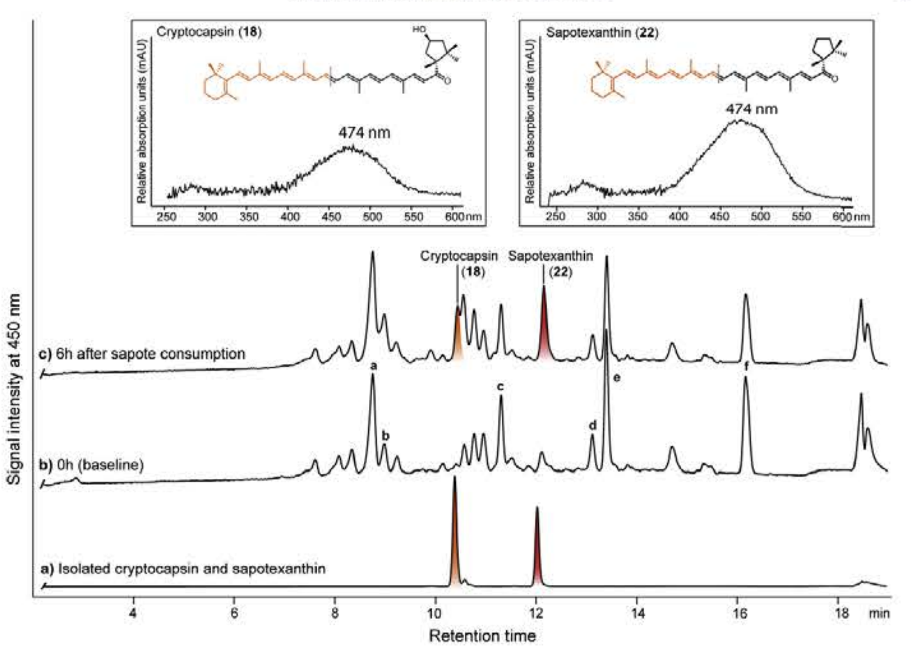


Fig. 3. Qualitative bioavailability of cryptocapsin and sapotexanthin from mamey sapote in humans. The figure displays HPLC-DAD separations of carotenoids from a) a saponified mamey sapote extract and of carotenoids from human TRL fractions at b) 0 h (baseline) and c) 6 h after the consumption of 300 g of a sapote fruit test meal, containing ca. 7.3 mg cryptocapsin, 2.5 mg sapotexanthin, and 15 g of added lipids. Detailed UV/Vis absorption spectra and the corresponding chemical structures are provided for cryptocapsin and sapotexanthin. Peak assignment in agreement with Kopec, Schweiggert, Riedl, Carle, and Schwartz (2013): a. Lutein, b. Zeaxanthin, c. β-cryptoxanthin, d. α-carotene, e. β-carotene, f. Lycopene.

Deposition Form and Bioaccessibility of Keto-carotenoids from Mamey Sapote (*Pouteria sapota*), Red Bell Pepper (*Capsicum annuum*), and Sockeye Salmon (*Oncorhynchus nerka*) Filet (Chacón-Ordóñez et al., 2016)

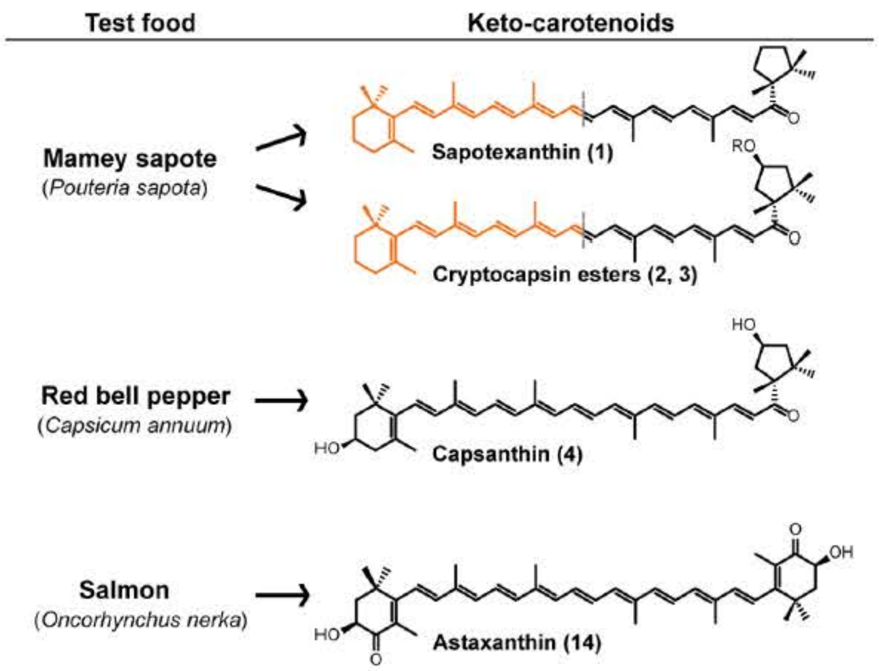


Figure 1. Structure of keto-carotenoids of mamey sapote, red bell pepper, and salmon. Dashed lines mark potential cleavage sites to obtain vitamin A.

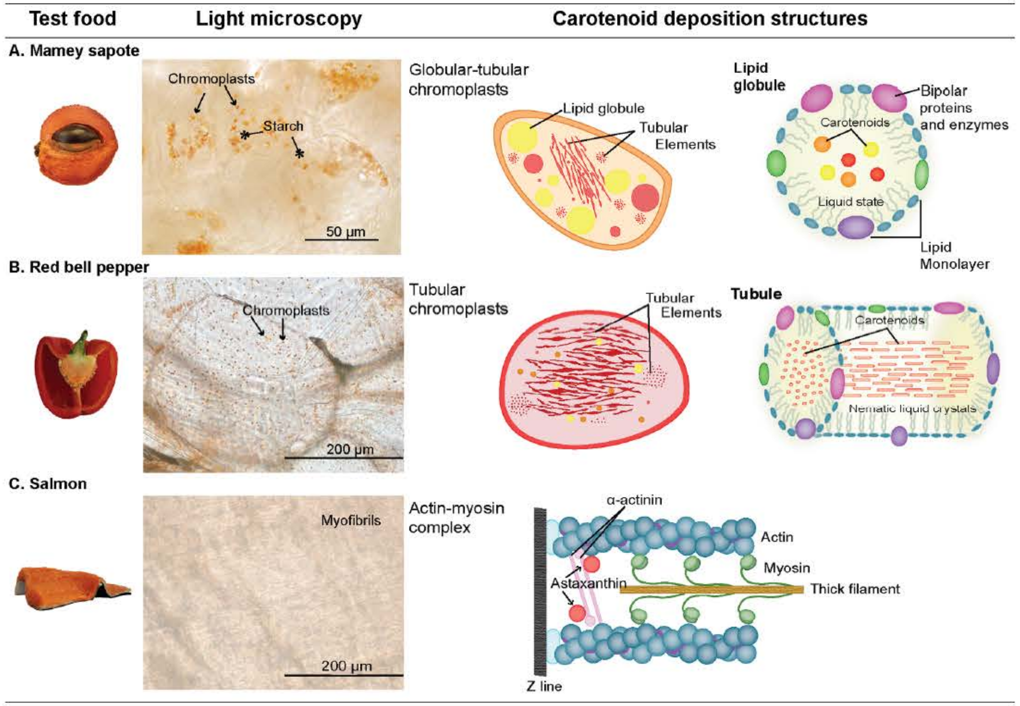
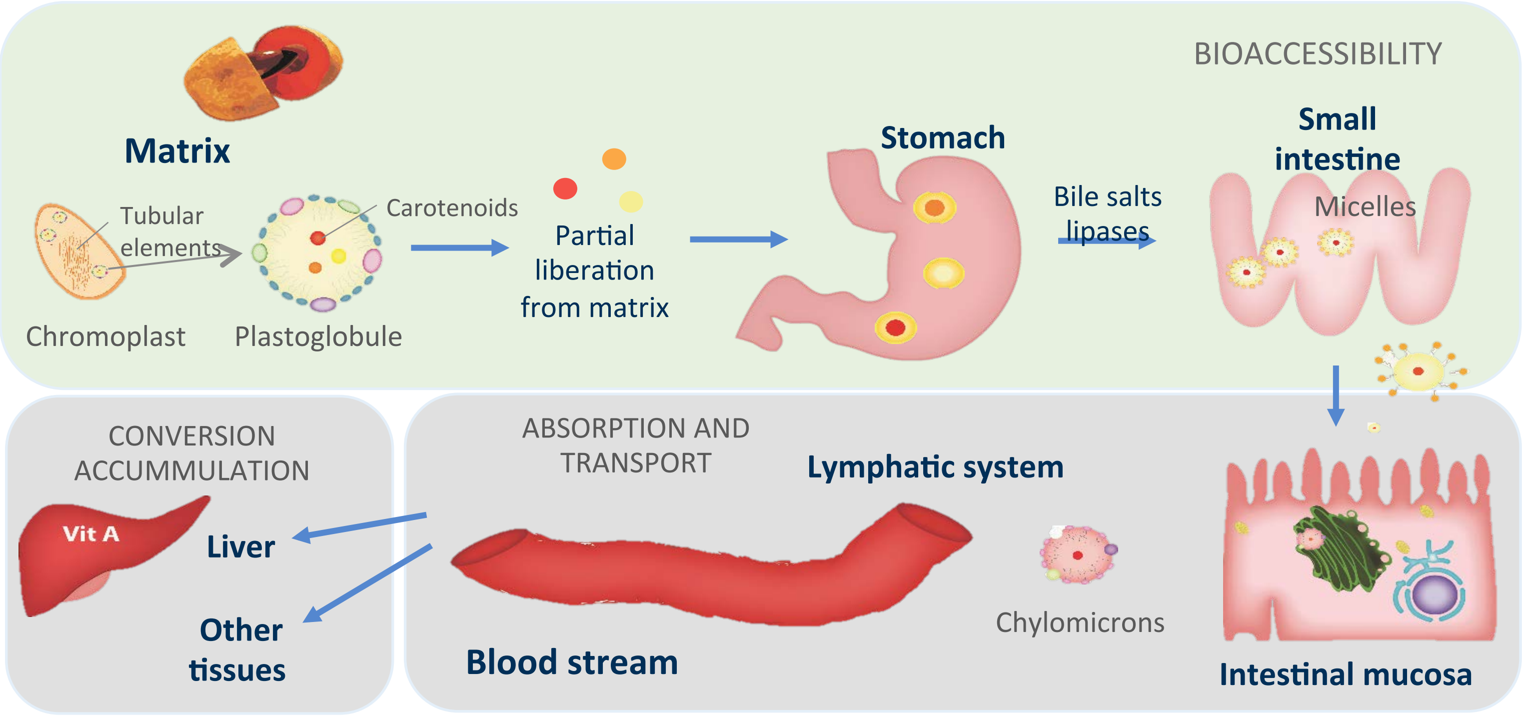


Figure 5. Deposition forms of keto-carotenoids in mamey sapote, red bell pepper, and salmon as shown by light microscopy images and detailed schematic diagrams of their carotenoid storage structures. (A) Mamey sapote fruits with globular−tubular chromoplasts and detailed view of lipid globule containing lipid-dissolved carotenoids. (B) Red bell pepper with tubular chromoplasts and detailed view of tubule containing a presumably liquid-crystalline carotenoid phase. (C) Salmon with astaxanthin associated with α-actinin in the actin−myosin complex inside muscle cells. The illustrations are based on content reported previously by Sitte[32] and Matthews et al.[20]



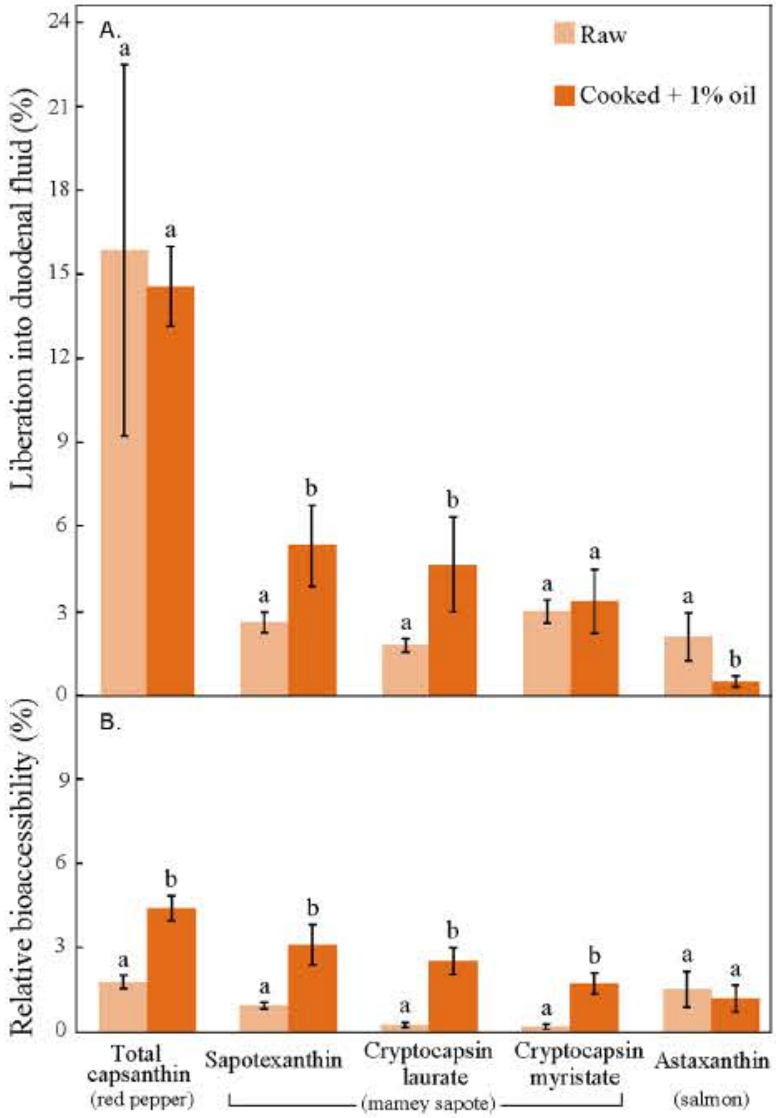


Figure 6. (A) Liberation and (B) bioaccessibility of keto-carotenoids from raw as well as from thermally treated (90 °C, 30 min) and lipid-enriched (+1% oil) test foods. Liberated carotenoids correspond to those recovered from the supernatant after centrifugation. Bioaccessible carotenoids and micellar fraction correspond to those obtained after microfiltration (0.2 μm) of the supernatant. Different letters indicate significant differences ($p < 0.05$) of the means between raw and cooked samples of the corresponding compound.

Characterization of phenolic compounds in jocote (Spondias purpurea L.) peels by ultra high-performance liquid chromatography/electrospray ionization mass spectrometry (Engels et al., 2012)

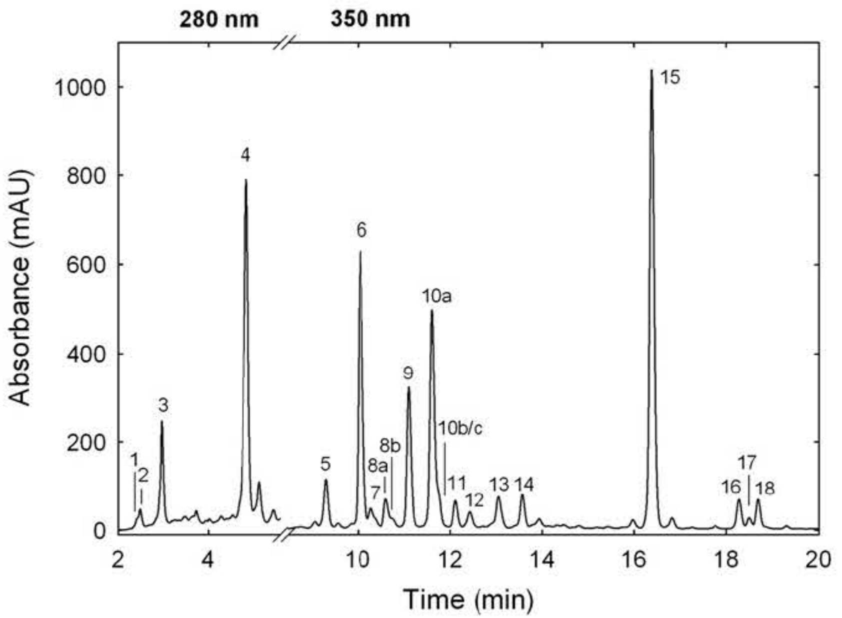


Fig. 1. Separation of phenolic acids (280 nm) and flavonol *O*-glycosides (350 nm) from jocote peels by ultra high-performance liquid chromatography. Peak assignment (see also Table 1): (1) galloyl glucose, (2) gallic acid, (3) di-hydroxybenzoic acid hexoside, (4) chlorogenic acid, (5) quercetin 3-*O*-pentosylrutinoside, (6) quercetin 3-*O*-pentosylhexoside, (7) quercetin rhamnosylhexoside, (8a) quercetin deoxyhexoside, (8b) quercetin pentoside, (9) rutin, (10a) quercetin 3-*O*-glucopyranoside, (10b) quercetin dipentoside, (10c) kaempferol deoxyhexosyl hexoside, (11) kaempferol hexosylpentoside, (12) quercetin 3-*O*-pentoside, (13) kaempferol 3-*O*-rutinoside, (14) kaempferol 3-*O*-glucoside, (15) rhamnetin hexosyl pentoside, (16) rhamnetin hexoside, (17) rhamnetin dipentoside, (18) kaempferide hexosyl pentoside.

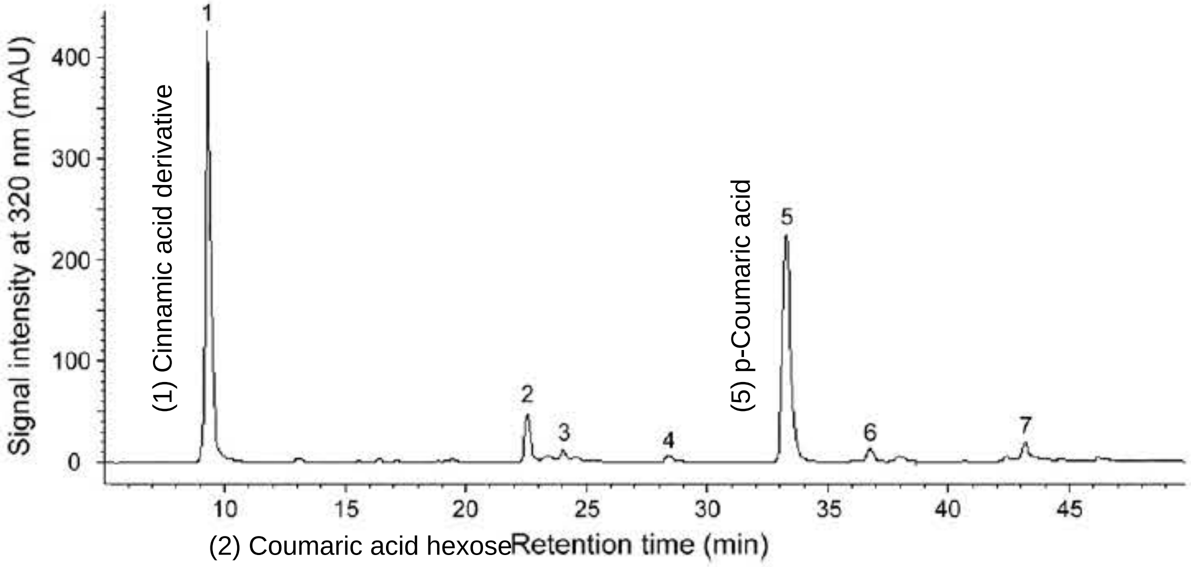


Fig. 1. HPLC separation of polyphenols from fraction I monitored at 320 nm. For peak assignment, see Table 1.

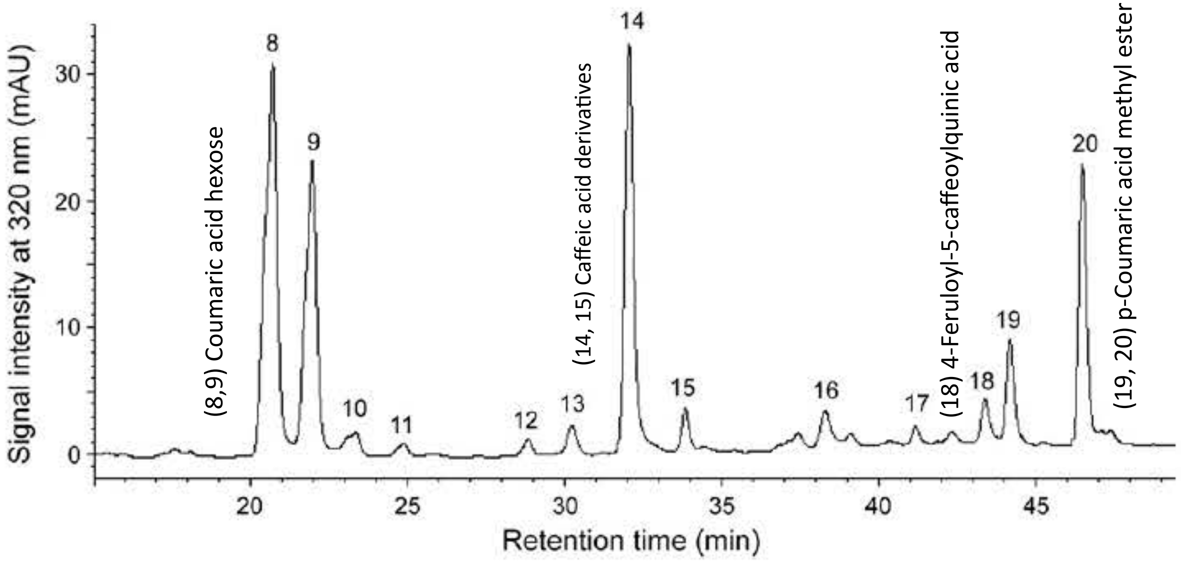


Fig. 2. HPLC separation of polyphenols from fraction II monitored at 320 nm. For peak assignment, see Table 2.

Identification of phenolic compounds in soursop (Annona muricata) pulp by high-performance liquid chromatography with diode array and electrospray ionization mass spectrometric detection (Jiménez et al., 2014)

Carotenoids, carotenoid esters, and anthocyanins of yellow-, orange-, and red-peeled cashew apples (Anacardium occidentale L.) (Schweiggert et al., 2016)

Fig. 1. Photograph of yellow-, orange-, and red-peeled cashew fruits. Brightness and contrast were adjusted with Adobe Photoshop (CS4).

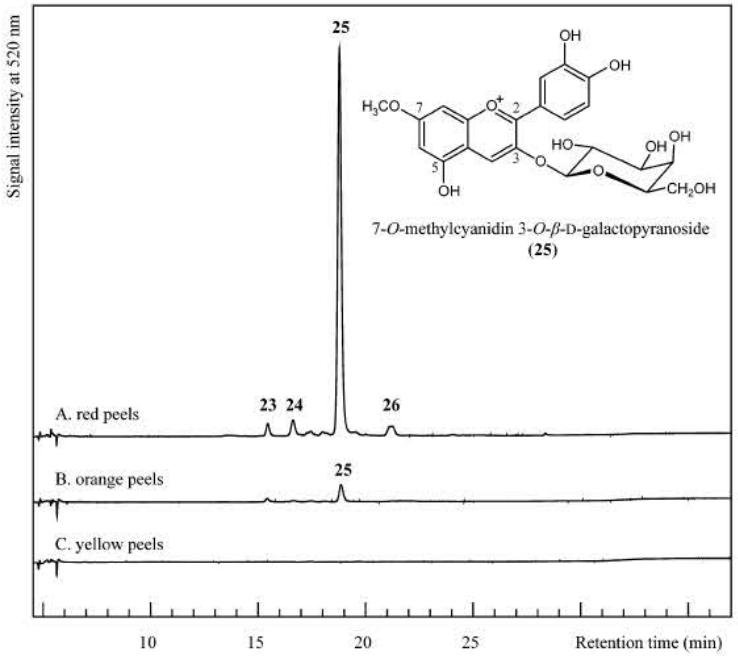


Fig. 3. HPLC separation of anthocyanins from the peels of differently colored cashew apples (monitored at 520 nm). In addition, the structure of 7-*O*-methylcyanidin 3-*O*-β-D-galactopyranoside (25) is shown.

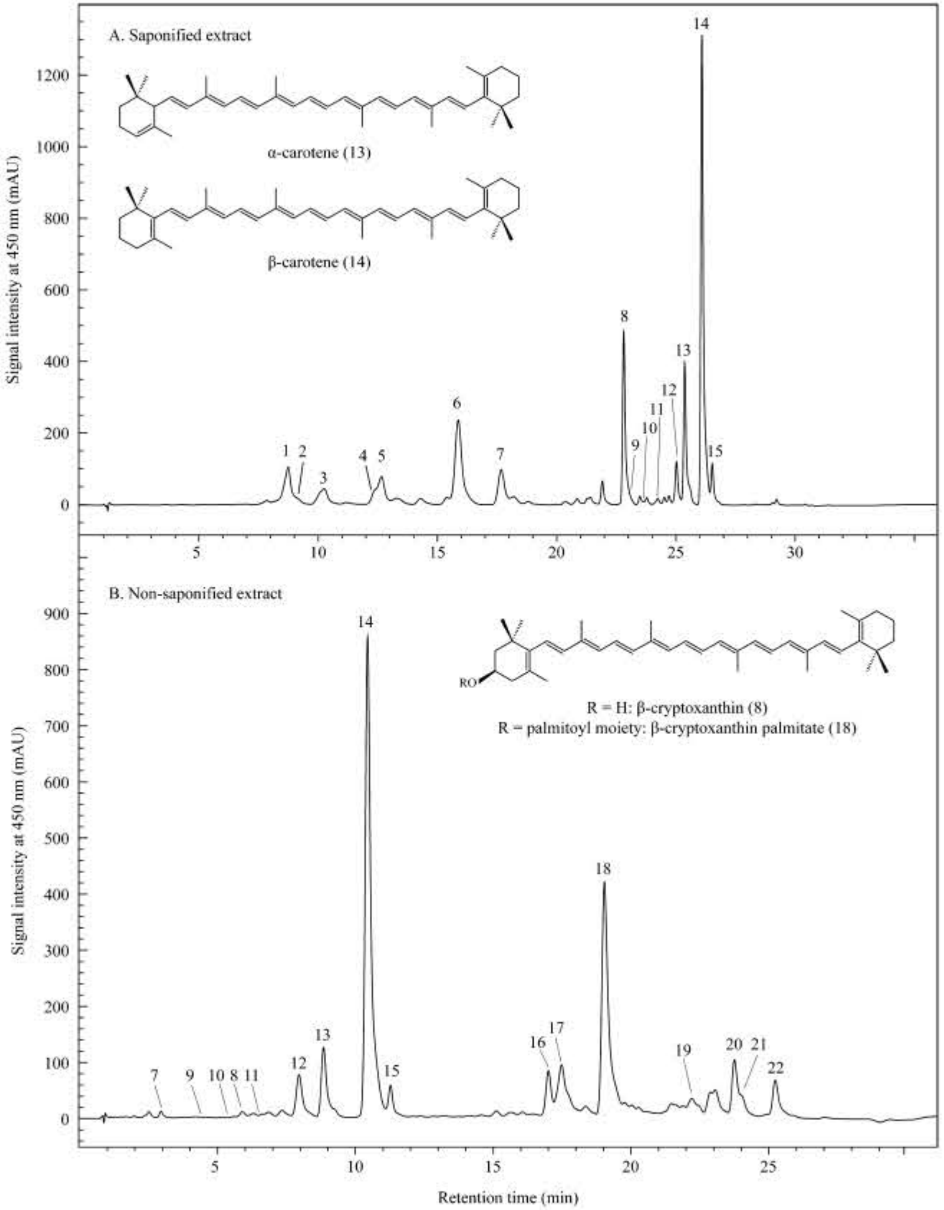


Fig. 2. HPLC separation of saponified (A) and non-saponified (B) carotenoid extracts of orange-peeled cashew apple, also depicting the structures of α-carotene (**13**), β-carotene (**14**), β-cryptoxanthin (**8**), and β-cryptoxanthin palmitate (**18**).

Lipid-dissolved c-carotene, b-carotene, and lycopene in globular chromoplasts of peach palm (Bactris gasipaes Kunth) fruits (Hempel et al., 2014)

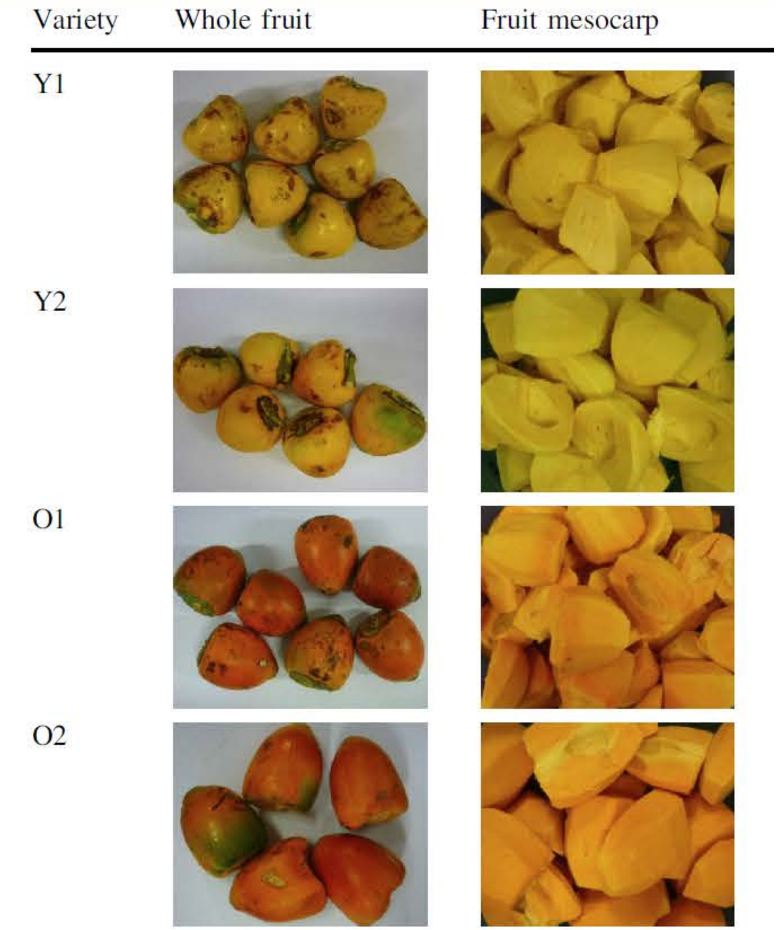
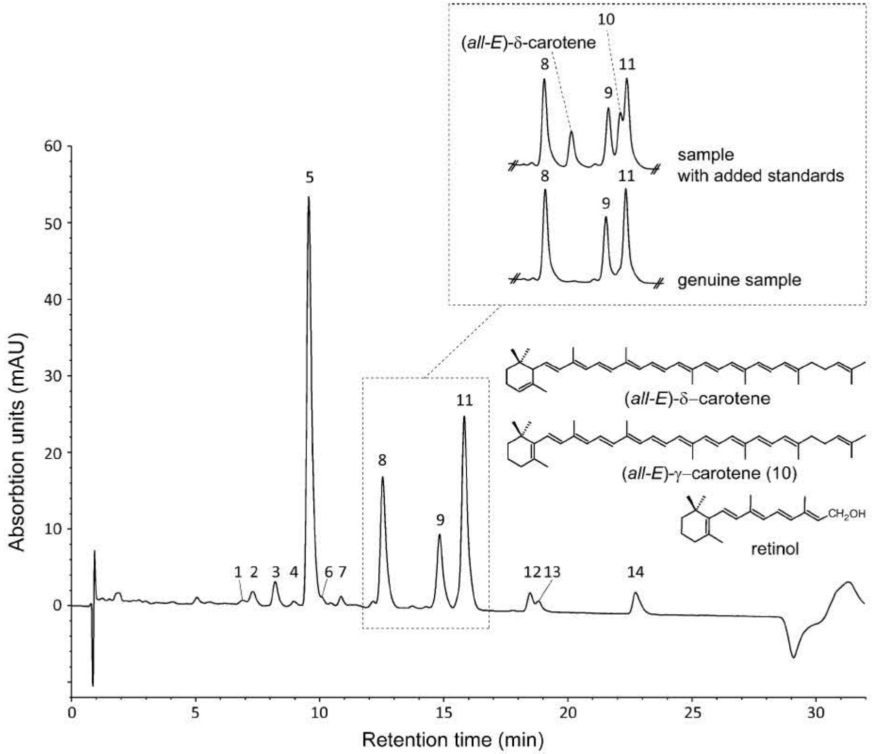
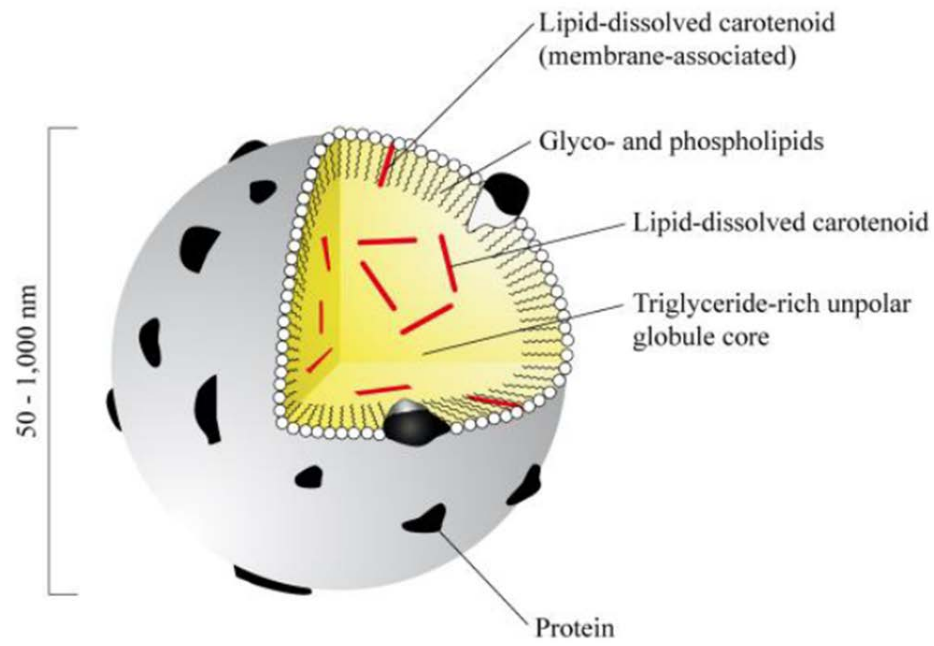


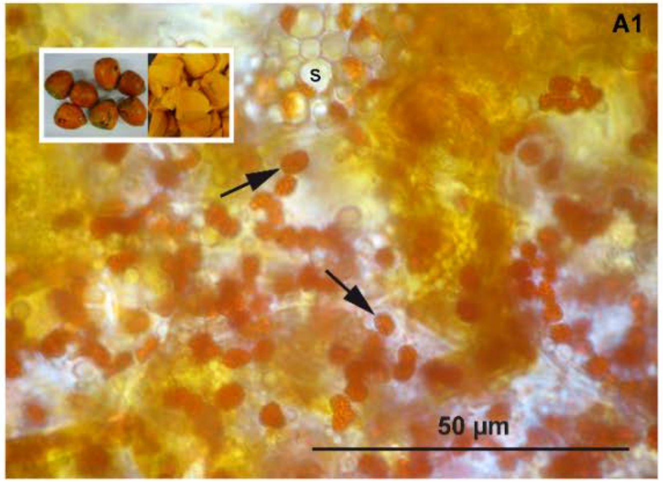
Fig. 1 HPLC separation of carotenoids from peach palm fruit mesocarp, monitored at 450 nm (variety O1). The detail (*dashed rectangle*) shows the comparison of a genuine sample and a sample containing added authentic standards of (*all-E*)-γ-carotene and (*all-E*)-δ-carotene. For peak assignment see Table 2

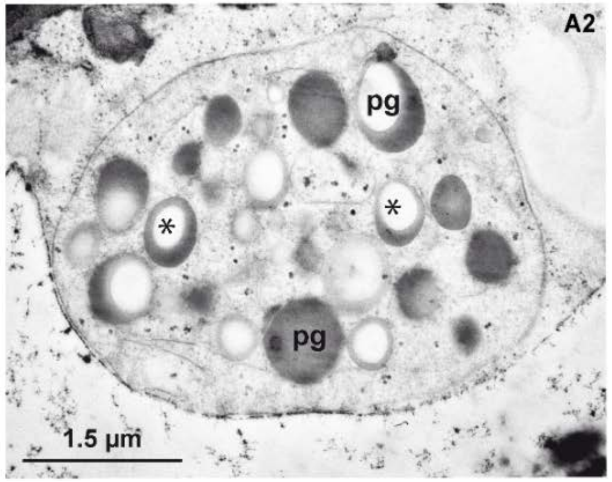


Total carotenoid content pertained to provitamin A carotenoids with retinol activity equivalents ranging from 37 to 609 µg/100 g FW

A. Plastoglobule



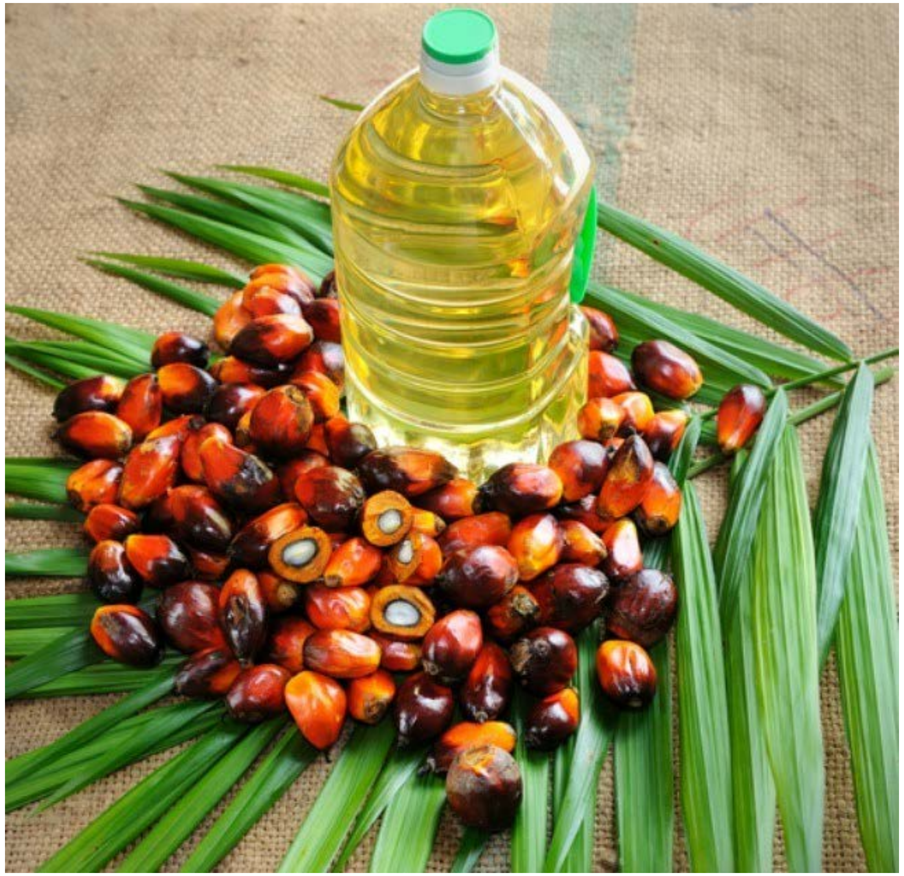




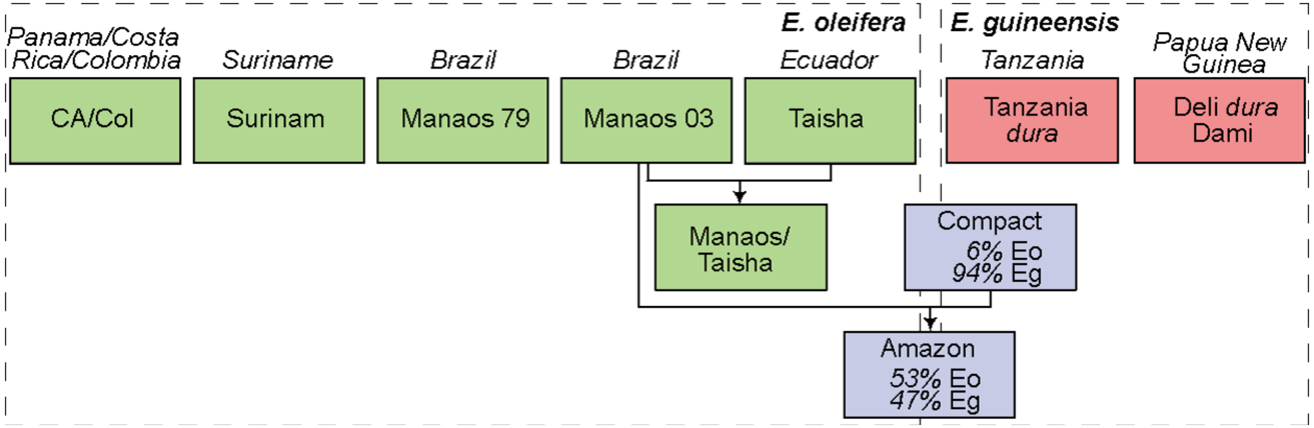
American oil palm (*Elaeis oleifera* (Kunth) Cortés)

African oil palm (*Elaeis guineensis* Jacq.) ranks first in the world as source of vegetable oil and carotene (coloring food additive E160a)

American oil palm (*Elaeis oleifera* (Kunth) Cortés) remains highly under-utilized to date

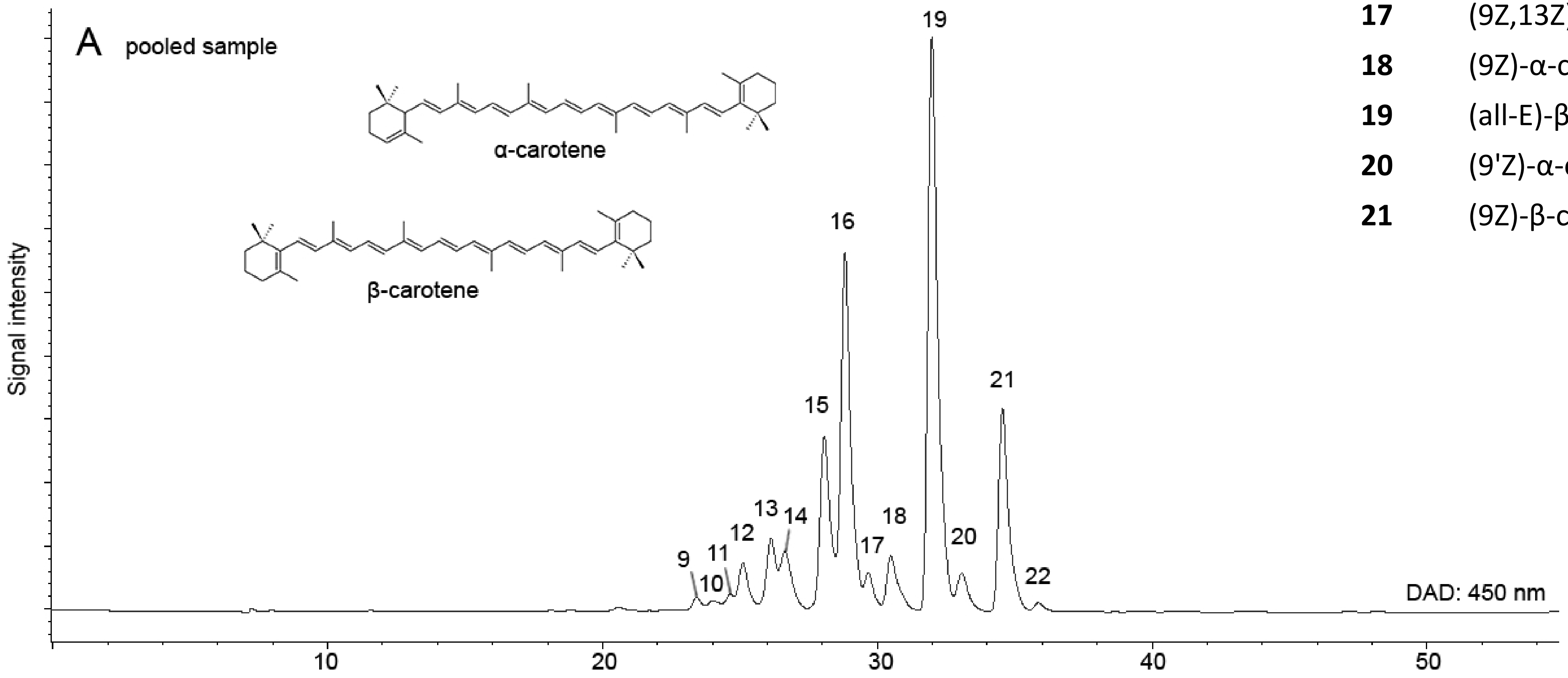


Oil palm fruit accessions, their genetic relationship, and geographic origin. *E. oleifera* (Eo), *E. guineensis* (Eg), and hybrids, are displayed in green, red, and blue boxes, respectively.



(Liet *et al.*, 2017)

Oil palm fruit accessions



12	(13Z)-α-carotene
13	(13'Z)-α-carotene
14	(Z)-β-carotene
15	(13Z)-β-carotene
16	(all-E)-α-carotene
17	(9Z,13Z)-β-carotene
18	(9Z)-α-carotene
19	(all-E)-β-carotene
20	(9'Z)-α-carotene
21	(9Z)-β-carotene

(Kerfers, 2016)

Carotenoid content and total carotenoids in µg/g oil in mesocarp, retinol activity equivalents (RAE) and isomer ratio (%) of various oil palm accessions.

	E. oleifera						*E. guineensis*		Hybrid		
Compound	CA/Col 03	Taisha 04	Surinam 79	Manaos 03	Manaos 79	Manaos/Taisha 12	Deli Dami 08	Tanzania 06	Compact 97	Amazon 12	Min.-max.
Total β-carotene	1308± 42c	569 ± 19e	2324 ± 0a	505± 21ef	1799± 150b	188 ± 21g	251 ± 24g	325 ± 71fg	222 ± 82g	896 ± 10d	164-2324
Total α-carotene	601 ± 25b	172 ± 1ef	1084± 23a	157± 13ef	572 ± 46bc	52 ± 6f	65 ± 9f	299 ± 98de	105 ± 34f	438 ± 23cd	48-1100
Others**	53 ± 5b	35 ± 3c	101± 4a	23 ± 1cd	67 ± 5b	15 ± 0d	16± 1d	28 ± 9cd	15 ± 1d	30 ± 2cd	14-104
Total carotenoids	1961± 73c	776 ± 15e	3509± 26a	686± 35ef	2439 ± 201b	254 ± 27g	332 ± 32fg	652 ± 178ef	342 ± 118fg	1364± 31d	236-3527
RAE (µg/g oil)a	96 ± 2c	40± 1e	172± 1a	36± 2ef	126± 10b	14 ± 1g	19 ± 2fg	29± 7efg	17 ± 7fg	67 ± 1d	12-173
Isomersb (%)	49± 2a	44 ± 1ab	48 ± 1ab	47 ± 1ab	48 ± 0ab	40 ± 1bc	34 ± 1c	45 ± 1ab	41 ± 6abc	48 ± 0ab	33-50

*Significant differences within a row are indicated by different letters tr.= trace, peak area< 10.000 or <0.9-2 µg/g oil n.d.= not detected

[a] retinol activity equivalents, calculated from α-, β- and γ-carotene isomers identified (1 µg RAE=1 µg retinol (Institute of Medicine, 2001)) [b] Isomers calculated from all assigned (*Z*)-isomers

** unknown compounds and γ-carotene

Values represent means ± standard deviation.

Crude red palm oils obtained from the mesocarp of African, American and hybrid oil palm fruits accumulate extremely high concentrations of provitamin A carotenoids, yielding average contents of 93 µg RAE/g.

(Kerfers, 2016)

Characterization of Mesocarp and Kernel Lipids from *Elaeis guineensis* Jacq., Elaeis oleifera [Kunth] Cortés, and Their Interspecific Hybrids (Lieb et al., 2017)

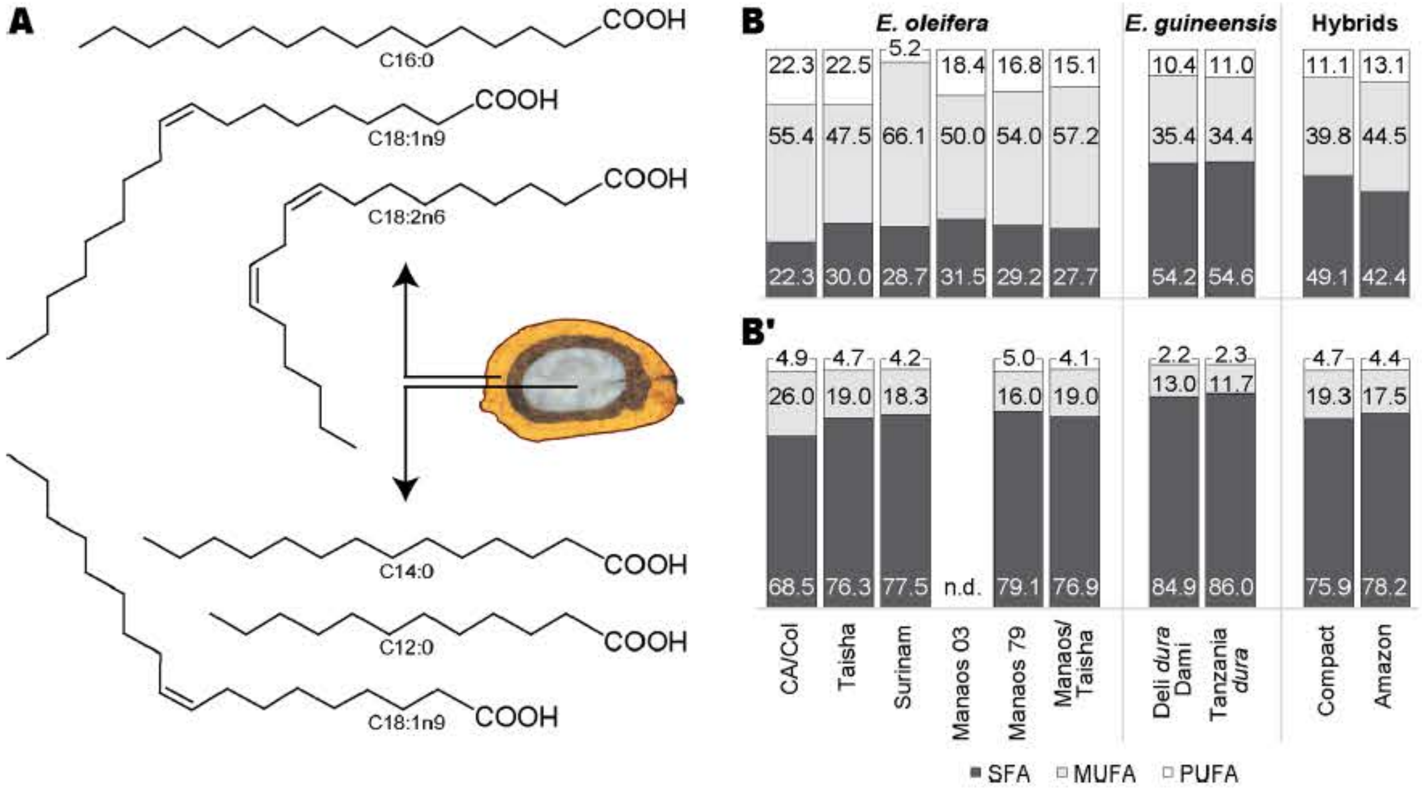


Figure 2. Structures of the most abundant fatty acids (A) among all samples. Relative abundance of SFA, MUFA, and PUFA (%) in (B) mesocarp and (B′) kernel oil.

Collaborative research projects between the University of Costa Rica, the University of Hohenheim and the Ohio State University

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Thank you for your attention!!