SUPPORTING INFORMATION

Non-Enzymatic β-Carotene Degradation in (Provitamin A-Biofortified) Crop Plants

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Analysis of volatile compounds

Volatile degradation products were analyzed with a Trace GC gas chromatograph coupled to a DSQ II (Thermo Fisher Scientific) mass detector. Thermo-desorption was carried out using a Thermal Desorber (Unity series 2, Markes Ltd). Separation was achieved on a TR-FAME column (Thermo Fisher Scientific, 30 m × 0.25 mm id × 0.25 µm film thickness) with a temperature gradient starting at 60°C, held isocratically for 2 min, followed by a temperature ramp of 12°C min^{-1} for 15 min. The final conditions were maintained for 2 min. Identification was done by spectral comparison with the NIST library and with the aid of authentic reference substances (Sigma). Quantification of β-ionone was performed by peak area comparison of the analyte with the D_3-β-ionone internal standard.

FOX-assays with rice grains

Polished seeds (1 g) were ground to a fine powder and incubated with 2 ml H_2O on ice in the dark for 30 min. After centrifugation (5 min, 3,200 x g) the supernatant was recovered and the pellet resuspended by sonication in 2 ml acetone containing 0,01 % butylated hydroxyl toluene (BHT) and 150 µl α-tocopherol-acetate for internal standardization. Following centrifugation, the supernatants were combined and the pellet was extracted twice with 3 ml $CHCl_3$: MeOH (1 : 1, v/v) containing 0,01 % BHT. The combined supernatants were adjusted to 14 ml with H_2O and mixed. After phase separation (5 min, 3,200 x g), the $CHCl_3$-phase was dried. The residue was dissolved in 300 µl $CHCl_3$: MeOH (1 : 1, v/v) and split into three 90 µl aliquots, one of which was used for the quantification of α-tocopherol-acetate by HPLC to correct for unspecific losses. The remaining aliquots were incubated for 30 min at ambient temperature in the dark after adding 10 µl MeOH or 10 µl 25 mM triphenylphosphine (TPP, in MeOH), respectively. Samples were mixed with 900 µl FOX-Reagent (250 µM ammonium ferrous sulfate, 100 µM xylenol orange, 25 mM H_2SO_4, 4 mM BHT in 90 % MeOH) and incubated for 30 min in the dark before recording UV/Vis spectra from 300 – 800 nm. The hydroperoxide content was calculated from the absorption at 560 nm (ε = 43,000 l mol^{-1} cm^1). The FOX signal difference between the MeOH- and TPP-treated samples represents the hydroperoxide content.

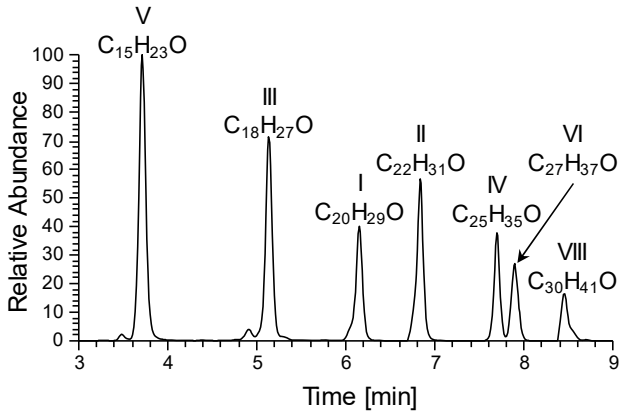

Figure 1S. Separation of β-carotene-derived apocarotenoids by LC-MS. Synthetic unlabeled apocarotenoid standards were separated and identified by extracting the exact mass of the individual molecular ions as given in the Methods section. Roman numerals refer to Figure 1.

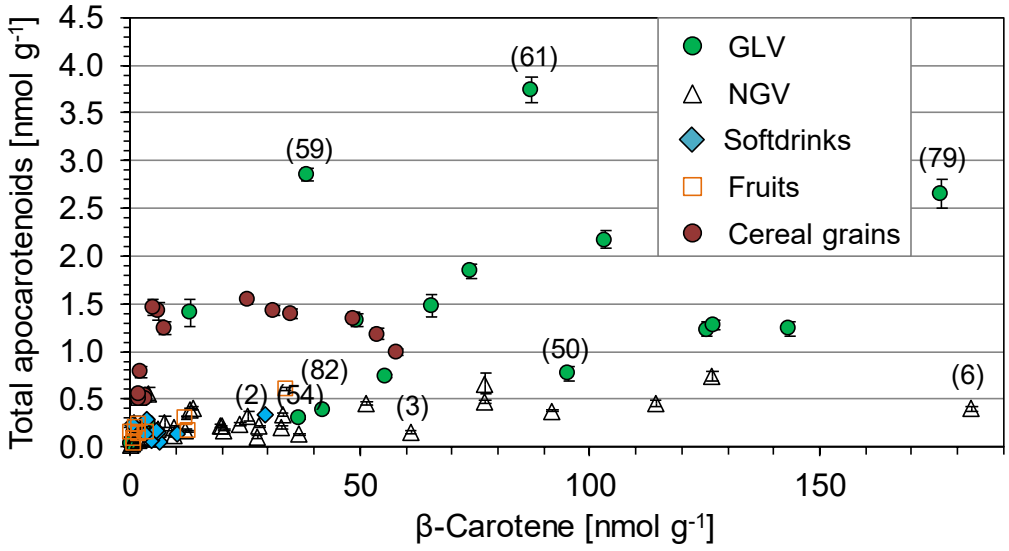

Figure 2S. Categorizing provitamin A (β-carotene) stability across plant tissues investigated. The ratio of β-carotene and β-carotene-derived apocarotenoids is used as a measure for stability; the most stable tissues plot close to the x-axis. Data are from Table S1. Numbers in brackets denote the respective entry numbers. The data are color-coded as given in the inset. For details, see text.

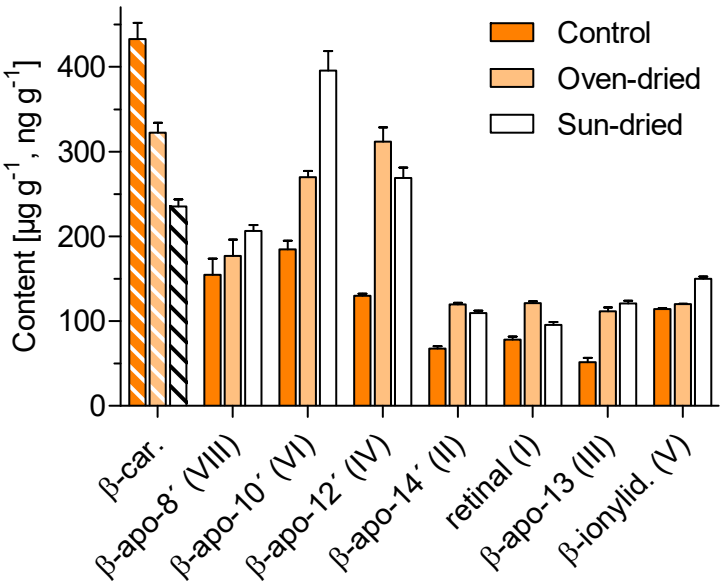

Figure 3S. Effect of drying on apocarotenoid formation. OFSP slices were lyophilized and analyzed directly (control), after oven drying at 70 °C for 4 h or after sun-drying for 12 h. β-carotene (hatched bars) is given in µg g^{-1}; the apocarotenoids, ordered according to their chain lengths, are given in ng g^{-1}. Note the discrepancies. The β-carotene loss is 111 µg upon oven drying and 197 µg upon sun drying, while the sum of apocarotenoids formed is 450 ng (0.4 %) and 566 ng (0.3 %), respectively. Roman numerals of cleavage products refer to Fig. 1. Data represent the mean ± SEM of three technical replicates.

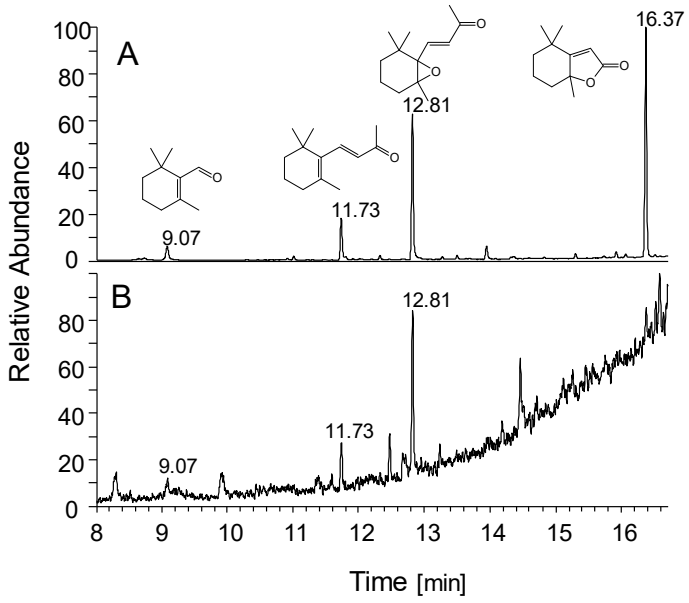

Figure 4S. GC-MS chromatogram of volatile β-carotene-derived degradation products. (A) Separation of volatiles extracted from decomposing OxBC polymer. (B) Separation of volatiles sampled from the headspace of 10 g GR for 4 days onto Tenax TA35/60 and analyzed by Thermo-Desorption GC-MS as outlined in the Methods section. Mass peaks were detected at their individual $[M^{\bullet}]^{+}$ and main fragments; (from left to right) β-cyclocitral 152→137; β-ionone 192→177, 5,6-epoxy-β-ionone 208→123 and dihydroactinidiolide 180→111.

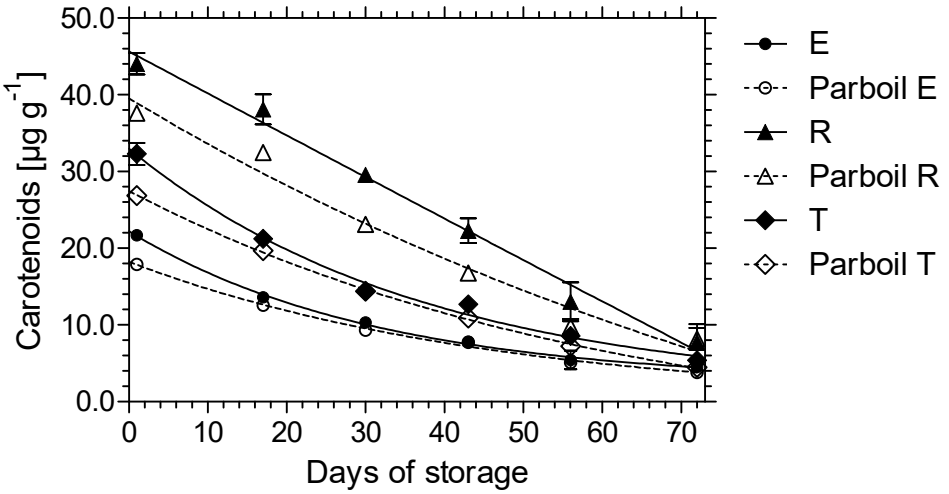

Figure 5S. Parboiling has no effect on β-carotene degradation kinetics. The decay of total carotenoids was assessed photometrically with experimental (cv. Kaybonnet) transgenic GR events (E, R, T). Parboiled samples (open symbols) were lower in content (reflecting ca. 80 % retention by the heat treatment) but revealed no substantial change in the degradation kinetics relative to the untreated controls (filled symbols). Data represent the mean ± SEM of two experiments.

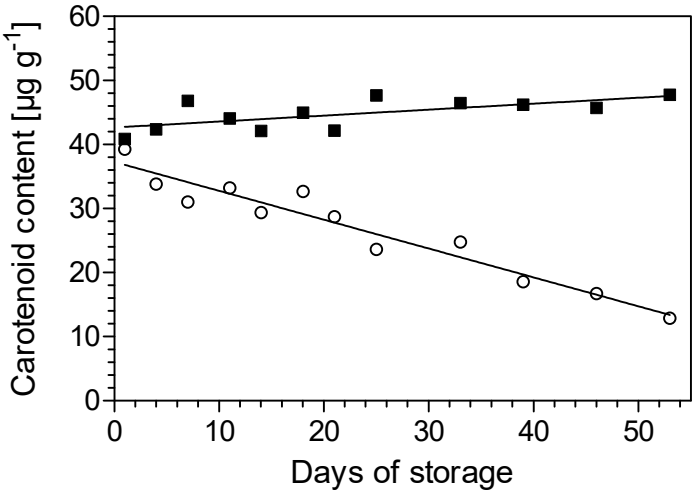

Figure 6S. Carotenoids do not degrade when GR grains are stored in an oxygen-free atmosphere. Grains were harvested 20 days after flowering and stored as paddy in the dark under atmospheric oxygen tension (circles) and in an anaerobic chamber providing a nitrogen atmosphere (squares). After the given times of storage, aliquots were milled, extracted and the carotenoid content was determined by LC-MS as given in the Methods section.

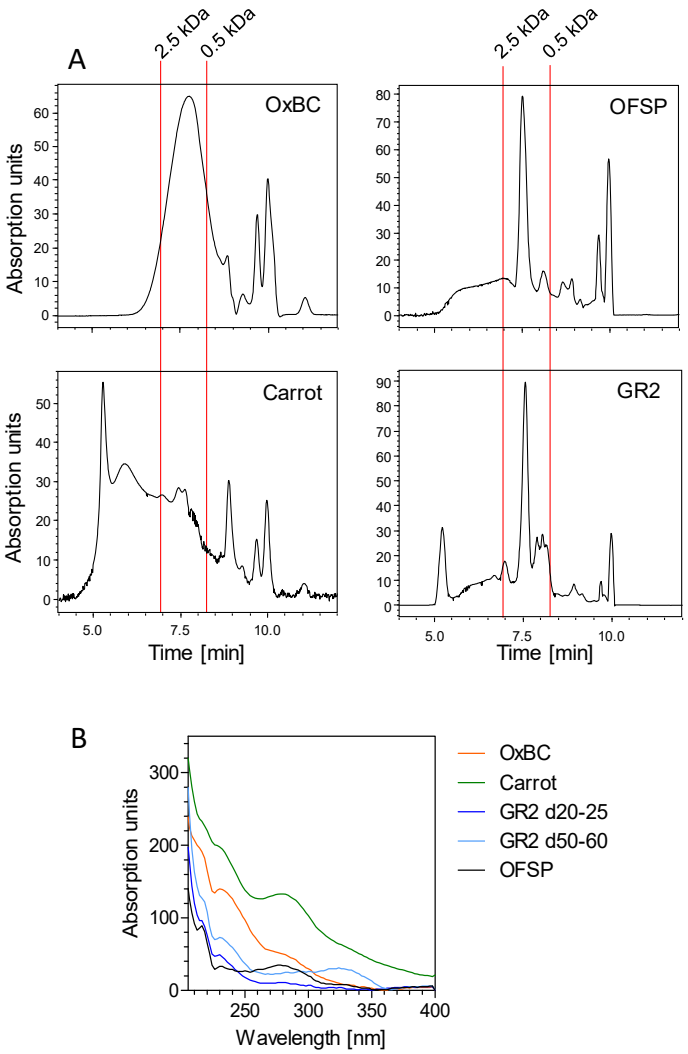

Figure 7S. GPC analysis of highly oxidized β-carotene polymers. (A) The polymeric fractions were isolated from different sources and subjected to GPC (photometric detection at 220-400 nm) as given in the Methods section. Polymeric oxidized β-carotene was produced as given in the methods section. The elution of size markers is indicated. (B) UV-VIS spectra of the polymeric fraction in MeOH solution. The fractions from GR were isolated after the given days of storage at ambient temperature.

Table 1S. β-Carotene and derived non-volatile β-apo-carotenoid content in food items. Data represent the mean (± SEM) of at least three technical replicates. Repetitive entries represent biological replicates originating (Orig) from different Philippine markets (L1-L5). Field-grown biofortified crops were from HarvestPlus (HP) or the greenhouse (FR). The categories (Cat) are (NGV) non-green vegetables; (C) cereal grains; (GLV) green leafy vegetables; (F) fruits; and (SD) soft drinks. β-carotene and apo-carotenoids were quantified by LC-MS as given in the Methods section. (nd) not detected; (trace) refers to compounds < than 50% (0.2 µg g^{-1} or ml^{-1}; β-carotene) and < 25% (2.5 ng g^{-1} or ml^{-1} for β-apo-8'-carotenal, 2.2 ng g^{-1} or ml^{-1} for β-apo-10'-carotenal, 2.1 ng g^{-1} or ml^{-1} for β-apo-12'-carotenal, 1.8 ng g^{-1} or ml^{-1} for β-apo-14'-carotenal, 1.7 ng g^{-1} or ml^{-1} for retinal, 1.5 ng g^{-1} or ml^{-1} for β-apo-13-carotenone, 1.3 ng g^{-1} or ml^{-1} for β-ionylidene-acetaldehyde) of the lowest amount on column used in the standard curves. The GoldenRice entries (19-27) refer to a storage time course experiment. Grains were harvested and stored at ambient temperatures in the dark (dah, days after harvest). The maize entries (7-11) refer to samples shipped for analysis after three months of storage at ambient temperature. OFSP, orange fleshed sweet potatoes

No	Food item	β-Carotene $C_{40}H_{56}$ [µg g^{-1}]	β-Apo-8`-carotenal $C_{30}H_{40}O$ [ng g^{-1}]	β-Apo-10`-carotenal $C_{27}H_{36}O$ [ng g^{-1}]	β-Apo-12`-carotenal $C_{25}H_{34}O$ [ng g^{-1}]	β-Apo-14`-carotenal $C_{22}H_{30}O$ [ng g^{-1}]	Retinal ($C_{20}H_{28}O$) [ng g^{-1}]	β-Apo-13-carotenone $C_{18}H_{26}O$ [ng g^{-1}]	β-ionylidene-acetaldehyde $C_{15}H_{22}O$ [ng g^{-1}]	Total apo-carotenoids [ng g^{-1}]	Apocar. Prop. [%]	English	Scientific	Cat.	Orig.
	Provitamin A-biofortified														
1	NASPOT13 O	61.3 ± 4.8	19.2 ± 4.0	28.7 ± 1.1	24.3 ± 1.9	16.1 ± 0.8	15.3 ± 1.6	24.7 ± 0.7	15.3 ± 0.9	143.6 ± 10.9	0.2	OFSP	*Ipomoea batatas*	NGV	HP
2	NASPOT12 O	14.8 ± 0.2	trace	5.3 ± 1.0	4.1 ± 0.6	3.4 ± 0.2	3.3 ± 0.2	6.6 ± 1.8	5.7 ± 0.8	30.2 ± 5.5	0.2	OFSP	*Ipomoea batatas*	NGV	HP
3	Kabode (NASPOT10 O)	32.8 ± 1.3	4.4 ± 0.3	8.0 ± 0.5	6.4 ± 1.3	5.2 ± 0.1	5.2 ± 0.8	8.3 ± 0.3	7.4 ± 1.2	44.8 ± 4.5	0.1	OFSP	*Ipomoea batatas*	NGV	HP
4	Vita (NASPOT9 O)	17.7 ± 0.6	8.2 ± 1.5	15.4 ± 0.3	11 ± 0.7	5.6 ± 0.4	6.1 ± 0.5	10.6 ± 0.3	7.7 ± 0.3	64.6 ± 4.0	0.4	OFSP	*Ipomoea batatas*	NGV	HP
5	Kakamega (SPK004)	19.7 ± 0.3	3.1 ± 0.7	7.3 ± 0.8	6.3 ± 1.0	4.0 ± 0.5	3.4 ± 0.5	7.2 ± 0.7	7.4 ± 0.2	38.7 ± 4.3	0.2	OFSP	*Ipomoea batatas*	NGV	HP
6	Ejumula	98.2 ± 1.2	13.4 ± 1	22.5 ± 1.8	21.3 ± 1.1	13.8 ± 0.6	11.8 ± 1.1	23.1 ± 0.7	15.3 ± 0.8	121.3 ± 7.1	0.1	OFSP	*Ipomoea batatas*	NGV	HP
7	Sammaz 38	1.9 ± 0.1	trace	30.9 ± 0.8	36.7 ± 1.5	5.9 ± 0.7	10.6 ± 0.6	65.0 ± 3.6	8.4 ± 0.7	158.4 ± 8.1	8.3	Maize	*Zea mays*	C	HP
8	Sammaz 39	1.0 ± 0.1	trace	29.6 ± 0.3	36.6 ± 0.6	nd	7.6 ± 0.9	79.5 ± 3.1	7.2 ± 0.9	160.6 ± 6.3	16.1	Maize	*Zea mays*	C	HP
9	Ife Hyb 3	1.3 ± 0.1	9.4 ± 1.7	33.6 ± 0.3	50.9 ± 3.3	1.8 ± 0.7	14.2 ± 0.6	110.4 ± 8.8	9.6 ± 0.6	229.9 ± 16.0	17.7	Maize	*Zea mays*	C	HP
10	Ife Hyb 4	1.8 ± 0.1	trace	31.9 ± 2.9	35.3 ± 0.4	2.1 ± 1.2	15.7 ± 0.9	59.3 ± 2.6	8.0 ± 1.1	153.8 ± 10.3	8.5	Maize	*Zea mays*	C	HP
11	Control ACR91	1.1 ± 0.1	trace	63.1 ± 3.6	26.9 ± 1.5	2.4 ± 0.3	8.4 ± 1.5	52.5 ± 2.7	5.0 ± 0.1	158.6 ± 10.8	14.4	Maize	*Zea mays*	C	HP
12	UMUCASS 36	10.5 ± 1.7	3.4 ± 1.1	9.5 ± 1.1	10.4 ± 1.2	5.9 ± 0.4	4.0 ± 0.8	8.3 ± 0.4	20.7 ± 1.6	62.3 ± 6.6	0.6	Cassava	*Manihot esculenta*	NGV	HP
13	UMUCASS 37	10.7 ± 1	3.1 ± 0.4	6.6 ± 0.9	9.0 ± 0.5	5.5 ± 0.6	4.7 ± 0.5	10.0 ± 1	20.0 ± 0.4	58.9 ± 4.3	0.6	Cassava	*Manihot esculenta*	NGV	HP
14	UMUCASS 38	12.9 ± 0.5	6.5 ± 0.3	7.8 ± 0.3	12.0 ± 0.1	5.9 ± 0.4	5.1 ± 0.7	12.4 ± 0.4	19.2 ± 1.4	68.8 ± 3.6	0.5	Cassava	*Manihot esculenta*	NGV	HP
15	UMUCASS 44	15.2 ± 0.9	3.4 ± 0.3	10.3 ± 0.9	9.2 ± 0.5	5.9 ± 0.3	4.9 ± 0.4	9.3 ± 0.1	17.8 ± 0.8	60.8 ± 3.3	0.4	Cassava	*Manihot esculenta*	NGV	HP
16	UMUCASS 45	11.0 ± 1.1	2.9 ± 0.2	7.5 ± 0.3	7.0 ± 1.0	4.3 ± 0.3	3.7 ± 0.6	8.0 ± 0.1	16.1 ± 1.6	49.5 ± 4.2	0.4	Cassava	*Manihot esculenta*	NGV	HP
17	UMUCASS 46	17.8 ± 0.7	8.5 ± 0.9	11.8 ± 0.5	15.3 ± 0.9	10.7 ± 0.2	8.0 ± 0.4	16.5 ± 1.3	26.2 ± 1.2	96.8 ± 5.3	0.5	Cassava	*Manihot esculenta*	NGV	HP
18	TMS 419	0.6 ± 0.0	trace	trace	trace	trace	nd	trace	11.0 ± 0.6	13.4 ± 1.1	2.2	Cassava	*Manihot esculenta*	NGV	HP
19	GR2E (dah 1)	31.1 ± 1.1	23.5 ± 2.1	77.4 ± 4.2	60.2 ± 0.2	32.3 ± 0.9	21.2 ± 0.6	81.3 ± 0.9	14.8 ± 0.8	310.7 ± 9.6	1.0	Golden Rice	*Otyza sativa*	C	FR
20	GR2E (dah 8)	28.9 ± 1.7	24.3 ± 0.8	78.1 ± 3.3	63.5 ± 1.8	40.8 ± 4.6	27.6 ± 1.6	101.8 ± 4	25.0 ± 1.0	361.1 ± 17.1	1.2	Golden Rice	*Otyza sativa*	C	FR
21	GR2E (dah 15)	26.1 ± 0.7	26.3 ± 2.0	87.3 ± 5.4	74.2 ± 3.3	47.2 ± 3.3	31.3 ± 0.8	112.3 ± 1.8	32.2 ± 1.1	410.8 ± 17.6	1.6	Golden Rice	*Otyza sativa*	C	FR
22	GR2E (dah 22)	18.9 ± 0.8	25.6 ± 1.0	87.4 ± 5.2	73.3 ± 3.7	48.8 ± 1.8	32.4 ± 1.1	117.6 ± 0.9	36.2 ± 1.9	421.3 ± 15.6	2.2	Golden Rice	*Otyza sativa*	C	FR
23	GR2E (dah 29)	16.8 ± 0.5	23.1 ± 1.6	93.6 ± 4.6	72.8 ± 2.1	51.8 ± 1.9	34.3 ± 0.7	119.9 ± 3.0	36.0 ± 1.2	431.5 ± 15.1	2.6	Golden Rice	*Otyza sativa*	C	FR
24	GR2E (dah 36)	13.7 ± 0.3	24.2 ± 1.4	95.7 ± 3.5	79.4 ± 4.0	56.5 ± 1.8	34.2 ± 1.8	136.8 ± 1.4	37.2 ± 1.9	464.0 ± 15.8	3.4	Golden Rice	*Otyza sativa*	C	FR
25	GR2E (dah 72)	4.1 ± 0.1	12.1 ± 4.2	85.6 ± 6.3	61.1 ± 4.1	58.0 ± 1.1	24.3 ± 1.1	110.2 ± 3.3	24.6 ± 1.2	375.9 ± 21.3	9.2	Golden Rice	*Otyza sativa*	C	FR
26	GR2E dah 160	3.3 ± 0.1	8.9 ± 0.7	104.0 ± 5.3	73.6 ± 8.8	65.8 ± 5.7	23.7 ± 2.5	136.1 ± 6.7	19.6 ± 0.3	431.7 ± 30.0	13.1	Golden Rice	*Otyza sativa*	C	FR
27	GR2E dah 215	2.7 ± 0.1	7.1 ± 0.5	109.7 ± 12.3	78.2 ± 4.9	75.3 ± 4.5	21.8 ± 1.1	138.1 ± 4.3	17.5 ± 0.4	447.7 ± 28.0	16.6	Golden Rice	*Otyza sativa*	C	FR
	Food basket Vegetables														
28	Camote	41.4 ± 3.1	23.3 ± 0.9	27.1 ± 1.1	22.2 ± 1.4	16.5 ± 0.5	17.2 ± 0.6	25.5 ± 0.5	16.2 ± 1.0	147.9 ± 6.2	0.4	Sweet potato tuber	*Ipomoea batatas*	NGV	L1
29	Camote	41.5 ± 3.3	21.0 ± 1.1	43.9 ± 5.5	23.0 ± 2.7	22.0 ± 4.7	21.8 ± 3.4	44.9 ± 10.5	24.1 ± 4.1	200.7 ± 32.1	0.5	Sweet potato tuber	*Ipomoea batatas*	NGV	L4
30	Egg plant	0.4 ± 0.1	trace	2.4 ± 0.3	trace	trace	trace	3.1 ± 0.3	2.6 ± 0.7	12.2 ± 1.9	3.1	Eggplant	*Solanum melongena*	NGV	L1
31	Egg plant native	trace	trace	2.5 ± 0.3	trace	trace	trace	6.9 ± 0.3	nd	13.3 ± 1.2	13.3	Eggplant	*Solanum melongena*	NGV	L3
32	Egg plant	trace	trace	3.4 ± 0.4	3.4 ± 0.1	1.9 ± 0.3	trace	5.8 ± 0.1	5.2 ± 1.1	21.3 ± 2.3	21.3	Eggplant	*Solanum melongena*	NGV	L4

No	Food item	β-Carotene $C_{40}H_{56}$ [µg g^{-1}]	β-Apo-8`-carotenal $C_{30}H_{40}O$ [ng g^{-1}]	β-Apo-10`-carotenal $C_{27}H_{36}O$ [ng g^{-1}]	β-Apo-12`-carotenal $C_{25}H_{34}O$ [ng g^{-1}]	β-Apo-14`-carotenal $C_{22}H_{30}O$ [ng g^{-1}]	Retinal ($C_{20}H_{28}O$) [ng g^{-1}]	β-Apo-13-carotenone $C_{18}H_{26}O$ [ng g^{-1}]	β-ionylidene-acetaldehyde $C_{15}H_{22}O$ [ng g^{-1}]	Total apo-carotenoids [ng g^{-1}]	Apocar. Prop. [%]	English	Scientific	Cat.	Orig.
33	String Beans	4.1 ± 0.1	6.2 ± 0.4	17.3 ± 0.4	14.3 ± 0.5	10.4 ± 0.5	5.9 ± 0.6	19.2 ± 13.6	6.1 ± 0.1	79.4 ± 16.0	1.9	String beans	*Phaseolus vulgaris*	NGV	L1
34	Sitao-stringbeans	2.3 ± 0.3	5.9 ± 0.5	23.9 ± 5.2	16.9 ± 1	16.2 ± 1.4	10.8 ± 1.6	73.3 ± 8.8	12.9 ± 0.5	159.9 ± 19.0	7.0	String beans	*Phaseolus vulgaris*	NGV	L3
35	String Beans	7.1 ± 0.2	5.6 ± 0.4	21.9 ± 0.4	14.5 ± 0.2	14.8 ± 0.4	10.3 ± 0.3	35.5 ± 1.0	13.8 ± 0.7	116.3 ± 3.4	1.6	String beans	*Phaseolus vulgaris*	NGV	L4
36	Bell Pepper Red	1.5 ± 0.1	5.6 ± 0.3	7.2 ± 0.8	5.0 ± 0.3	3.5 ± 0.3	3.8 ± 0.2	4.0 ± 0.2	2.8 ± 0.2	31.8 ± 2.3	2.1	Red bell pepper breaker	*Capsicum annuum*	NGV	L1
37	Bell pepper red	5.2 ± 0.7	3.1 ± 0.5	15.6 ± 0.8	7.7 ± 0.5	9.8 ± 0.5	5.9 ± 0.0	15.9 ± 0.1	5.9 ± 0.0	63.9 ± 2.4	1.2	Red bell pepper	*Capsicum annuum*	NGV	L3
38	Red bell pepper	1.1 ± 0.1	5.0 ± 0.0	4.7 ± 0.6	3.9 ± 0.1	2.7 ± 0.2	2.9 ± 0.1	2.9 ± 0.2	2.7 ± 0.2	24.8 ± 1.4	2.3	Red bell pepper breaker	*Capsicum annuum*	NGV	L4
39	Sibuyas Tagalog	trace	trace	trace	trace	trace	trace	trace	2.1 ± 0.6	4.9 ± 1.9	--	Red Onion	*Allium cepa*	NGV	L1
40	Sibuyas Tagalog	trace	trace	trace	trace	trace	trace	trace	trace	3.0 ± 1.3	--	Red Onion	*Allium cepa*	NGV	L4
41	Red Onion Local	nd	trace	trace	trace	trace	trace	trace	1.4 ± 0.2	2.2 ± 0.3	--	Onion	*Allium cepa*	NGV	L1
42	Onion Bombay-sibuyas	nd	trace	trace	nd	trace	trace	trace	1.8 ± 0.9	2.7 ± 1.0	--	Onion	*Allium cepa*	NGV	L3
43	Onion red local	nd	trace	trace	nd	trace	trace	trace	trace	1.7 ± 0.3	--	Onion	*Allium cepa*	NGV	L3
44	Onion white	nd	trace	trace	nd	trace	3.1 ± 2.7	nd	8.1 ± 6.3	11.8 ± 9.2	--	Onion	*Allium cepa*	NGV	L3
45	Onion white	nd	trace	trace	trace	trace	2.2 ± 0.4	nd	nd	3.4 ± 1.0	--	Onion	*Allium cepa*	NGV	L4
46	Cabbage	0.2 ± 0.1	trace	trace	trace	trace	trace	2.3 ± 0.0	3.0 ± 1.3	9.3 ± 2.0	4.7	Cabbage	*Brassica oleracea*	NGV	L1
47	Cabbage red	nd	trace	trace	trace	trace	trace	trace	nd	2.5 ± 0.2	--	Cabbage	*Brassica oleracea*	NGV	L2
48	Cabbage	nd	trace	3.5 ± 0.3	2.8 ± 0.2	trace	trace	6.2 ± 0.2	5.5 ± 0.9	20.8 ± 2.0	--	Cabbage	*Brassica oleracea*	NGV	L3
49	Cabbage	0.2 ± 0.0	trace	3.1 ± 0.3	2.7 ± 0.2	trace	trace	3.7 ± 0.1	2.5 ± 0.1	15.2 ± 0.9	7.6	Cabbage	*Brassica oleracea*	GLV	L4
50	Carrots	49.3 ± 3.5	12.8 ± 0.2	24.1 ± 0.6	14.0 ± 0.2	17.9 ± 0.8	12.7 ± 0.1	22.9 ± 0.4	11.8 ± 0.6	116.4 ± 2.8	0.2	Carrot roots	*Daucus carota*	NGV	L1
51	Carrots	68.0 ± 9.1	12.9 ± 0.7	39.6 ± 0.9	22.3 ± 0.5	32.4 ± 2.9	23.5 ± 1.6	64.5 ± 4.5	22.2 ± 1.7	217.5 ± 12.8	0.3	Carrot roots	*Daucus carota*	NGV	L3
52	Carrots	13.8 ± 1.7	6.8 ± 0.5	18.2 ± 1.7	10.2 ± 0.8	15.0 ± 1.0	10.9 ± 1.1	25.2 ± 3.2	10.0 ± 3.7	96.3 ± 11.9	0.7	Carrot roots	*Daucus carota*	NGV	L4
53	Wombok P. Baguio)	trace	trace	trace	trace	trace	trace	trace	trace	4.4 ± 1.6	4.4	Chinese cabbage	*Brassica rapa*	NGV	L1
54	Pechay Native	19.7 ± 1.7	11.5 ± 1.8	25.1 ± 1.3	12.7 ± 0.4	11.9 ± 0.4	9.6 ± 0.5	15.7 ± 0.2	8.3 ± 0.4	94.8 ± 4.9	0.5	Pak Choi	*Brassica rapa*	GLV	L2
55	Pechay Baguio (wombok)	27.6 ± 1	12.3 ± 1.8	30.7 ± 0.3	19.8 ± 0.7	20.6 ± 0.5	13.1 ± 0.8	33.0 ± 1.1	10.0 ± 0.5	139.6 ± 5.8	0.5	Chinese cabbage	*Brassica rapa*	NGV	L3
56	Pechay Tagalog	2.2 ± 0.4	2.5 ± 0.2	16.5 ± 0.9	16.4 ± 0.5	10.0 ± 1.0	7.1 ± 0.2	17.4 ± 1.5	9.1 ± 1.2	79.0 ± 5.3	3.6	Local cabbage	*Brassica rapa*	GLV	L4
57	Pechay Baguio	trace	trace	trace	trace	trace	trace	trace	trace	2.7 ± 0.3	--	Chinese cabbage	*Brassica rapa*	NGV	L4
58	Kangkong	29.8 ± 2.3	17.5 ± 0.5	49.1 ± 0.7	33.4 ± 1.4	19.5 ± 1.2	15.8 ± 1	74.3 ± 1.3	14.2 ± 0.4	223.8 ± 6.4	0.8	Water spinach	*Ipomoea aquatica*	GLV	L1
59	Kangkong	20.7 ± 1.0	21.3 ± 0.3	128.7 ± 2.3	96.0 ± 2.5	93.8 ± 3.1	47.1 ± 0.6	338.9 ± 7.8	87.9 ± 3.5	813.5 ± 20.1	3.9	Water spinach	*Ipomoea aquatica*	GLV	L3
60	Kangkong	39.8 ± 0.7	21.6 ± 1.7	100.6 ± 1.9	54.7 ± 2.7	57.9 ± 1.9	42.4 ± 2.3	152.1 ± 2.2	97.4 ± 7.8	526.7 ± 20.5	1.3	Water spinach	*Ipomoea aquatica*	GLV	L4
61	Camote Tops	26.5 ± 2.9	27.4 ± 0.7	83.8 ± 2.0	56.1 ± 3.3	41.3 ± 3.2	24.1 ± 2.6	138.0 ± 8.8	27.1 ± 0.7	397.8 ± 21.2	1.5	Sweet potato leaves	*Ipomoea batatas*	GLV	L1
62	Camote Tops	46.8 ± 7.6	39.5 ± 2.6	172.3 ± 5.8	113.8 ± 8.8	127.2 ± 6.6	83.0 ± 4.7	350.7 ± 2.2	175.3 ± 10.5	1061.8 ± 41.2	2.3	Sweet potato leaves	*Ipomoea batatas*	GLV	L4
63	Ycon (Sugar Beets)	trace	trace	trace	trace	trace	1.8 ± 0.5	trace	2.0 ± 0.3	10.6 ± 1.6	--	Sugar beet	*Beta vulgaris*	NGV	L1
64	Sugar Beets	nd	trace	trace	trace	trace	trace	nd	1.5 ± 0.3	2.2 ± 0.5	--	Beet root	*Beta vulgaris*	NGV	L4
65	Malunggay	149.8 ± 3.6	34.2 ± 1.0	62.8 ± 1.1	37.7 ± 1.8	35.7 ± 0.2	27.6 ± 1.4	63.2 ± 1.5	23.5 ± 0.9	284.6 ± 7.8	0.2	Drumstick tree	*Moringa oleifera*	GLV	L1
66	Malunggay	77.0 ± 4.9	50.1 ± 2.4	91.1 ± 2.7	55.5 ± 1.5	47.9 ± 2.8	36.6 ± 2.8	75.0 ± 7.0	31.1 ± 1.1	387.2 ± 20.4	0.5	Drumstick tree	*Moringa oleifera*	GLV	L5
67	Squash	7.4 ± 0.1	8.1 ± 0.5	18.4 ± 0.8	16.8 ± 0.4	10.6 ± 0.2	8.0 ± 0.4	49.7 ± 3.5	7.7 ± 0.3	119.3 ± 6.0	1.6	Squash	*Cucurbita spec.*	NGV	L2
68	Squash	5.2 ± 0.5	5.0 ± 0.8	11.2 ± 0.6	5.3 ± 0.4	3.5 ± 0.2	3.8 ± 0.3	6.2 ± 0.3	3.2 ± 0.2	38.1 ± 2.8	0.7	Squash	*Cucurbita spec.*	NGV	L3
69	Squash	6.6 ± 0.4	7.9 ± 0.9	13.4 ± 0.9	7.2 ± 0.2	5.5 ± 0.1	5.7 ± 0.3	8.2 ± 0.3	5.9 ± 0.3	53.7 ± 3.0	0.8	Squash	*Cucurbita spec.*	NGV	L4
70	Tomato red	2.1 ± 0.3	3.8 ± 0.2	9.9 ± 0.8	10.4 ± 0.3	4.7 ± 0.5	4.8 ± 0.7	12.6 ± 0.1	8.5 ± 1.5	54.6 ± 4.1	2.6	Tomato	*Solanum lycopersicum*	NGV	L2
71	Tomato native	1.0 ± 0.5	trace	6.3 ± 1.2	4.9 ± 0.3	2.6 ± 0.5	2.2 ± 1.0	4.8 ± 0.5	9.1 ± 1.3	31.7 ± 5.0	3.2	Tomato	*Solanum lycopersicum*	NGV	L3
72	Tomato tagalog	1.8 ± 0.3	trace	6.9 ± 0.2	5.8 ± 0.3	3.5 ± 0.4	2.4 ± 0.4	7.2 ± 0.1	3.7 ± 0.3	31.7 ± 1.8	1.8	Tomato	*Solanum lycopersicum*	NGV	L4
73	Okra	2.3 ± 0.2	5.8 ± 0	5.8 ± 0.2	5.0 ± 0.5	2.0 ± 1.7	4.1 ± 0.6	3.7 ± 0.1	3.4 ± 0.1	29.8 ± 3.2	1.3	Okra	*Abelmoschus esculentus*	NGV	L2
74	Okra	1.9 ± 0.2	8.9 ± 0.6	16.5 ± 1.1	12.7 ± 0.9	8.6 ± 0.5	6.7 ± 0.6	15.2 ± 0.8	6.1 ± 0.5	74.7 ± 4.9	3.9	Okra	*Abelmoschus esculentus*	NGV	L3
75	Okra	3.4 ± 0.1	7.4 ± 0.5	14.6 ± 1.7	7.9 ± 0.3	7.1 ± 0.3	5.6 ± 0.2	9.9 ± 0.9	4.6 ± 0.3	57.0 ± 4.2	1.7	Okra	*Abelmoschus esculentus*	NGV	L4
76	Baguio Beans	0.5 ± 0.2	trace	10.4 ± 0.5	8.2 ± 0.4	5.0 ± 0.3	3.9 ± 1.1	9.7 ± 0.7	29.1 ± 14.7	67.6 ± 18.0	13.5	Local green beans	*Phaseolus vulgaris*	NGV	L2
77	Baguio Beans	trace	trace	13.2 ± 2.4	11.1 ± 0.7	7.7 ± 0.4	4.6 ± 0.4	15.9 ± 0.5	10.6 ± 1.4	64.3 ± 6.0	64.3	Local green beans	*Phaseolus vulgaris*	NGV	L4
78	Sili leaves	55.5 ± 2.3	28.6 ± 1.7	128.9 ± 4.8	73 ± 2.2	70.6 ± 2.2	49.7 ± 2.7	167.8 ± 4.5	108.7 ± 7.7	627.3 ± 25.8	1.1	Bell pepper leaves	*Capsicum annuum*	GLV	L2
79	Sili leaves	94.7 ± 5	34.6 ± 1.6	107.4 ± 4.6	71.9 ± 1.6	75.3 ± 3.9	68.7 ± 5.2	191.3 ± 5.4	186.4 ± 18.3	735.4 ± 40.5	0.8	Bell pepper leaves	*Capsicum annuum*	GLV	L4
80	Ampalaya	nd	trace	3.7 ± 0.5	2.9 ± 0.5	2.0 ± 0.3	1.7 ± 0.3	1.5 ± 1.4	nd	12.8 ± 3.1	--	Bitter melon	*Momordica charantia*	NGV	L2
81	Amplaya-bittergourd	trace	nd	trace	trace	trace	trace	2.4 ± 0.1	3.0 ± 0.0	9.5 ± 0.5	4.8	Bitter melon	*Momordica charantia*	NGV	L4
82	Mustasa	22.5 ± 0.4	14.5 ± 1.5	29.5 ± 3.3	15.8 ± 0.2	16.9 ± 1.5	12.4 ± 0.4	20.3 ± 0.8	10.0 ± 0.1	119.4 ± 7.7	0.5	Mustard greens	*Brassica juncea*	GLV	L2
83	Mustard Native	7.0 ± 2.2	7.5 ± 0.9	85.9 ± 16.9	87.6 ± 6.6	47.4 ± 3.6	22.1 ± 1.2	122.3 ± 10.3	44.8 ± 4.9	417.7 ± 44.3	6.0	Mustard greens	*Brassica juncea*	GLV	L4
84	Cucumber	trace	trace	7.4 ± 1	6.5 ± 0.2	4.4 ± 0.2	3.0 ± 0.3	15.8 ± 1.4	6.3 ± 0.6	44.6 ± 4.0	44.6	Cucumber	*Cucumis sativus*	NGV	L2
85	Cucumber	trace	trace	trace	trace	trace	trace	1.5 ± 0.2	3.4 ± 0.8	10.2 ± 1.6	--	Cucumber	*Cucumis sativus*	NGV	L4
86	Gabi native tuber	nd	trace	trace	trace	trace	trace	trace	2.8 ± 1.0	5.4 ± 1.3	--	Taro tuber	*Colocasia esculenta*	NGV	L3
87	Gabi Tagalog tuber	nd	trace	trace	trace	trace	trace	trace	1.7 ± 0.7	3.0 ± 1.0	--	Taro tuber	*Colocasia esculenta*	NGV	L4

No	Food item	β-Carotene $C_{40}H_{56}$ [µg g^{-1}]	β-Apo-8`-carotenal $C_{30}H_{40}O$ [ng g^{-1}]	β-Apo-10`-carotenal $C_{27}H_{36}O$ [ng g^{-1}]	β-Apo-12`-carotenal $C_{25}H_{34}O$ [ng g^{-1}]	β-Apo-14`-carotenal $C_{22}H_{30}O$ [ng g^{-1}]	Retinal ($C_{20}H_{28}O$) [ng g^{-1}]	β-Apo-13-carotenone $C_{18}H_{26}O$ [ng g^{-1}]	β-ionylidene-acetaldehyde $C_{15}H_{22}O$ [ng g^{-1}]	Total apo-carotenoids [ng g^{-1}]	Apocar Prop. [%]	English	Scientific	Cat.	Orig.
88	Gabi tuber	trace	trace	trace	trace	trace	trace	nd	trace	2.4 ± 0.4	--	Taro tuber	*Colocasia esculenta*	NGV	L2
89	Green mongo	trace	trace	trace	trace	trace	trace	2.9 ± 0.7	8.0 ± 0.5	14.7 ± 1.7	14.7	Mung bean	*Vigna radiata*	NGV	L3
90	Green mongo	0.3 ± 0.0	trace	trace	2.5 ± 0.2	trace	trace	3.4 ± 0.3	4.3 ± 0.2	14.0 ± 1.3	4.7	Mung bean	*Vigna radiata*	NGV	L6
91	Laing (dried)	183.2 ± 6.4	206.2 ± 12.6	418.9 ± 8.6	498.4 ± 15	215.4 ± 22.4	143.5 ± 16.3	1401.6 ± 82.5	221.1 ± 27.8	3105.1 ± 185.3	1.7	Taro leaves	*Colocasia esculenta*	GLV	L3
92	Gabi-taro leaves (dried)	268.7 ± 13.6	216.2 ± 5.7	678.3 ± 84.5	570.8 ± 80.2	391.5 ± 52.0	281.5 ± 32.9	1833.8 ± 171.6	597.2 ± 99.0	4569.3 ± 525.7	1.7	Taro leaves	*Colocasia esculenta*	GLV	L4
93	Fresh gabi laing	67.3 ± 3.3	49.3 ± 8.8	97.2 ± 3.8	52.5 ± 6.4	51.8 ± 1.1	34.5 ± 2.0	73.9 ± 1.5	28.7 ± 1.4	387.8 ± 25.0	0.6	Taro leaves	*Colocasia esculenta*	GLV	L5
94	Fresh gabi-laing	68.1 ± 0.5	26.9 ± 1.7	266.8 ± 8.2	30.2 ± 1.1	30.8 ± 1.5	22.1 ± 0.3	40.4 ± 3.6	17.8 ± 0.5	434.9 ± 16.9	0.6	Taro leaves	*Colocasia esculenta*	GLV	L6
95	Alugbati	35.2 ± 1.2	21.7 ± 3.7	70.2 ± 2.2	42.6 ± 1.0	43.5 ± 3.5	37.5 ± 1.8	85.3 ± 6.2	111.6 ± 12.5	412.4 ± 30.9	1.2	Vine spinach	*Basella alba*	GLV	L4
96	Alugbati	51.2 ± 3.3	11.6 ± 0.9	35.2 ± 2.3	21.9 ± 1.8	22.1 ± 2.5	18.6 ± 1.1	44.8 ± 3.4	59.4 ± 9.3	213.7 ± 21.3	0.4	Vine spinach	*Basella alba*	GLV	L2
97	Luyang dilaw-turmeric	nd	nd	nd	nd	nd	nd	nd	nd	nd	--	Turmeric root	*Curcuma longa*	NGV	L4
98	Luyang dilaw	nd	2.6 ± 0.8	trace	5.4 ± 0.9	2.4 ± 0.2	nd	4.0 ± 0.3	nd	15.0 ± 2.7	--	Turmeric root	*Curcuma longa*	NGV	
99	Sigarilyas	1.4 ± 0.2	trace	9.9 ± 1.5	9.1 ± 0.5	6.0 ± 0.4	4.9 ± 0.6	17.3 ± 0.8	8.9 ± 1.3	56.7 ± 5.2	4.1	Winged bean	*Psophoc. tetragonolobus*	NGV	L4
100	Sigarilyas	1.1 ± 0.4	trace	27.2 ± 5.6	23.6 ± 1.1	15.7 ± 2.4	12.5 ± 0.5	38.7 ± 1.0	28.6 ± 2.1	148.6 ± 12.8	13.5	Winged bean	*Psophoc. tetragonolobus*	NGV	L5
	Food basket Fruits														
101	Mangoe ripe, kinalabaw	18.2 ± 0.4	13.0 ± 1.5	51.2 ± 0.8	24.6 ± 1	25.1 ± 0.1	19.0 ± 0.4	40.6 ± 0.8	14.2 ± 0.5	187.7 ± 5.0	1.0	Mango	*Mangifera indica*	F	L2
102	Mango ripe, kinalabaw	6.8 ± 0.3	5.0 ± 0.1	11.6 ± 0.2	7.5 ± 0.2	6.1 ± 0.3	5.9 ± 0.1	10.6 ± 0.5	4.3 ± 0.4	51.0 ± 1.7	0.8	Mango	*Mangifera indica*	F	L3
103	Mango ripe kinalabaw	6.6 ± 0.3	10.4 ± 0.3	22.3 ± 1.4	13.8 ± 0.7	11.2 ± 0.3	11.0 ± 0.1	19.1 ± 0.2	7.3 ± 0.1	95.0 ± 3.1	1.4	Mango	*Mangifera indica*	F	L4
104	Sinta papaya	0.7 ± 0.3	trace	18.2 ± 0.8	9.8 ± 0.5	6.0 ± 1.1	6.4 ± 0.5	8.9 ± 0.7	12.5 ± 1.7	64.1 ± 5.4	9.2	Papaya	*Carica papaya*	F	L2
105	Papaya	nd	trace	3.3 ± 0.7	2.0 ± 0.1	trace	trace	trace	5.6 ± 0.9	15.1 ± 2.2	--	Papaya	*Carica papaya*	F	L3
106	Papaya	trace	trace	2.4 ± 0.2	trace	trace	trace	1.6 ± 0.0	5.1 ± 0.1	13.8 ± 0.7	13.8	Papaya	*Carica papaya*	F	L4
107	Banana saba	0.2 ± 0.0	4.3 ± 0.3	8.7 ± 0.6	5.2 ± 0.1	6.1 ± 0.3	4.1 ± 0.2	14 ± 0.4	4.2 ± 0.1	46.5 ± 2.0	23.3	Saba banana	*Musa acuminata × balbisiana*	F	L2
108	Saging Saba-banana saba	1.9 ± 0.2	4.5 ± 0.9	9.7 ± 0.6	5.6 ± 0.1	5.7 ± 0.5	4.9 ± 0.1	11.6 ± 0.6	5.0 ± 0.4	47.1 ± 3.1	2.5	Saba banana	*Musa acuminata × balbisiana*	F	L4
109	Banana Lakatan	1.0 ± 0.0	3.6 ± 0.3	8.2 ± 0.6	5.1 ± 0.2	4.8 ± 0.2	3.6 ± 0.2	9.6 ± 0.5	4.4 ± 0.2	39.2 ± 2	3.9	Lakatan banana	*Musa acuminata 'Lakatan'*	F	L4
110	Pineapple Dole tropical	nd	trace	trace	trace	trace	trace	trace	4.1 ± 1.1	6.5 ± 1.7	--	Pineapple	*Ananas comosus*	F	L3
111	Pineapple	nd	trace	trace	trace	trace	trace	trace	2.4 ± 0.2	6.6 ± 1.5	--	Pineapple	*Ananas comosus*	F	L4
112	Guava	trace	trace	trace	trace	trace	trace	trace	1.3 ± 0.3	2.3 ± 0.5	1.2	Guava	*Psidium guajava*	F	L4
113	Calamansi	nd	trace	5.3 ± 0.0	2.1 ± 0.2	trace	trace	3.5 ± 0.9	5.7 ± 1.5	19.2 ± 3.1	--	Calamondin	*Citrofortunella microcarpa*	F	L4
114	Calamansi	0.6 ± 0.0	trace	5.0 ± 0.9	trace	trace	trace	1.7 ± 0.1	2.5 ± 0.7	12.9 ± 2.1	2.2	Calamondin	*Citrofortunella microcarpa*	F	L5
115	Water melon yellow	0.6 ± 0.1	trace	7.8 ± 0.4	6.3 ± 0.2	trace	2.2 ± 0.3	4.8 ± 0.5	5.7 ± 0.3	30.6 ± 1.7	5.1	Watermelon	*Citrullus lanatus var. lanatus*	F	L4
116	Water melon yellow	trace	nd	trace	2.9 ± 0.7	nd	trace	2.5 ± 0.2	6.5 ± 2.1	15.5 ± 4.2	15.5	Watermelon	*Citrullus lanatus var. lanatus*	F	L6
117	Water melon red	1.1 ± 0.1	trace	12.6 ± 2.0	9.7 ± 0.5	8.8 ± 1.0	6.1 ± 0.5	16.8 ± 2.1	13.1 ± 1.5	69.2 ± 7.6	6.3	Watermelon	*Citrullus lanatus var. lanatus*	F	L4
118	Native orange	nd	trace	11.1 ± 1.1	11.1 ± 1.3	4.0 ± 0.7	3.2 ± 0.2	12.2 ± 2.4	6.0 ± 1.1	48.7 ± 7.1	--	Orange	*Citrus sinensis*	F	L4
119	Native orange	nd	trace	trace	trace	trace	trace	1.5 ± 0.2	trace	7.1 ± 1.2	--	Orange	*Citrus sinensis*	F	L5
	Food basket Soft Drinks	[µg/ml]	[ng/ml]	[ng/ml]	[ng/ml]	[ng/ml]	[ng/ml]	[ng/ml]	[ng/ml]	[ng/ml]					
120	Tropicana Fruit Burst	5.6 ± 0.2	3.2 ± 0.2	6.1 ± 0.1	6.0 ± 0.3	6.4 ± 0.4	10.9 ± 0.1	5.7 ± 0.1	2.6 ± 0.3	41 ± 1.5	0.7			SD	L2
121	Tropicana Juicy Pulp	2.1 ± 0	11.4 ± 0.4	18.3 ± 0.6	15.1 ± 1.3	10.6 ± 0.1	7.3 ± 0.2	14.0 ± 0.4	11.1 ± 1.1	87.7 ± 4.1	4.2			SD	L2
122	Tropicana Mango	2.6 ± 0.1	2.9 ± 0.2	4.3 ± 0.1	5.3 ± 0.1	2.4 ± 0.2	4.2 ± 0.2	4.1 ± 0.1	1.6 ± 0.1	24.7 ± 1	1.0			SD	L2
123	Minute Maid Mango Orange	3.4 ± 0.1	trace	2.6 ± 0.1	3.7 ± 0.1	trace	2.2 ± 0.3	2.6 ± 0.1	2.8 ± 0.2	17.0 ± 0.9	0.5			SD	L2
124	Minute Maid Four Seasons	3.3 ± 0.3	3.5 ± 0.2	7.4 ± 0.2	5.8 ± 0.2	6.7 ± 0.1	8.7 ± 0.5	9.8 ± 0.1	3.7 ± 0.1	45.6 ± 1.4	1.4			SD	L2
125	Zesto Slice Orange	0.4 ± 0.0	82 ± 3.1	trace	trace	trace	nd	trace	8.3 ± 0.6	95.8 ± 3.8	24.0			SD	L2
126	Del Monte Sweetend Orange	1.9 ± 0.1	5.8 ± 0.2	6.6 ± 0.2	8.6 ± 0.4	5.5 ± 0.1	4.0 ± 0.1	9.5 ± 0.1	3.8 ± 0.2	43.8 ± 1.3	2.3			SD	L2
127	Del Monte Pineapple Orange	3.2 ± 0.2	5.0 ± 0	7.5 ± 0.3	9.5 ± 0.9	8.1 ± 0.5	5.6 ± 0.4	12.7 ± 1.4	5.2 ± 0.1	53.7 ± 3.5	1.7			SD	L2
128	Del Monte Four Seasons	15.9 ± 0.6	7.6 ± 0.4	13.3 ± 0.5	26.6 ± 1.1	17.2 ± 0.3	9.9 ± 0	20.5 ± 0.5	8.2 ± 0.6	103.3 ± 3.3	0.6			SD	L2
129	Del Monte Pineapple	trace	trace	trace	trace	trace	trace	trace	trace	7.0 ± 0.4	3.5			SD	L2

Table 2S. Extrapolation of RAE and apo-carotenoids exposure of GR and selected plant food items. The data given relate to the grid line indicators given in Figure 12 and provide the number values on exposure to the selected three β-carotene derived apocarotenoids. Data are derived from Table S1. Note that with the exception of mango (consumed fresh) an 80 % β-carotene cooking retention is assumed. For further explanation, see text.

Food item	Target RAE [µg]	Amount needed [g]	β-apo-14'-carotenal intake [µg]	Retinal intake [µg]	β-apo-13-carotenone intake [µg]	∑ Apocar. intake [µg]
GR2E (dah 29; 3.8:1)	500	141	7.32	4.85	16.95	29.12
Alugbati (10:1)	500	145	4.75	4.06	9.41	18.21
Alugbati (19:1)	500	275	9.02	7.71	17.88	34.61
Camote Tops (10:1)	500	171	14.37	9.13	41.67	65.17
Camote Tops (19:1)	500	324	27.30	17.35	79.17	123.82
Carrot (15:1)	500	160	3.48	2.51	6.00	11.99
Mango(12:1)	500	570	8.05	6.82	13.35	28.22