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Carotenoid and polyphenol content of Heritage tomatoes

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1 Background

The Heritage Food Crops Research Trust is interested in understanding the health benefits of tomato. The aim of the present investigation was to determine the polyphenol and carotenoid content of 25 tomato cultivars.

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2 Materials and methods

Twenty-five cultivars of tomato provided by Mark Christensen, Heritage Food Crops (Laboratory Reference: SC67), were stored at −20ºC upon arrival at PFR, Palmerston North until analysis. Of these, 24 cultivars were included in the analysis. Unfortunately one sample, ‘Tangella’, was unable to be located.

To obtain a representative sample for chemical analysis, the frozen tomato fruit was homogenised with dry ice. The number of fruit per sample ranged from one to thirteen. Cherry tomato type samples contained more individual fruit than samples that were of standard or large sized fruit. A subsample of the frozen homogenised tomato fruit was extracted with solvent for carotenoid (tetrahydrofuran/methanol) or polyphenol (ethanol/Milli Q water/formic acid) analysis. Carotenoid content was determined by high performance liquid chromatography with diode array detection (HPLC-DAD). Polyphenol content was determined by high performance liquid chromatography mass spectrometry (HPLC-MS). Each component was quantified by comparison with an authentic standard, with the following exceptions:

- Tetra-cis lycopene – quantified as all-trans lycopene equivalents
- Crypto-chlorogenic acid – quantified as chlorogenic acid equivalents
- (*E*)-caffeoyl 3-glucoside (unknown 1) – quantified as caffeic acid equivalents
- Quercetin 3-xylosylrutinoside (unknown 2) – quantified as quercetin rutinoside equivalents
- Naringenin chalcone (unknown 3) – quantified as trans-4-*p*-coumaroylquinic acid equivalents.

The quantitative results are expressed on a per weight basis (mg/100 g fresh weight (FW)). Appendix 1 contains a table of the detected compounds and their associated CAS numbers.

3 Results

Carotenoid concentrations of the 24 analysed tomato cultivars are shown in Table 1.

Table 1. Concentrations (mg/100 g fresh weight (FW)) of known carotenoid compound in samples of tomato fruit measured by high performance liquid chromatography with diode array detection (HPLC-DAD). Carotenoids measured were all-trans (AT) and tetra-cis (TC) lycopene, lutein and beta-carotene (β-carotene). These compounds were not detected (n.d.) in all samples. Two separate samples were received for 'Moonglow' and 'Olga's Round Golden Chicken Egg.' These were also analysed as separate samples.

Sample	Received	TC-lycopene	Lutein	ß-carotene	AT-lycopene
'Amish Yellowish Orange Oxheart'	22/1/2020	7.05	n.d.	n.d.	n.d.
'B'mato'	17/1/2020	3.65	n.d.	n.d.	n.d.
'Golden Bell' (Beachman's)	23/1/2020	7.61	0.12	n.d.	n.d.
'Blazing Beauty'	17/1/2020	4.95	n.d.	n.d.	n.d.
'Bob Logan Tomato'	17/1/2020	5.38	n.d.	n.d.	n.d.
'Golden Eye' (original)	17/1/2020	n.d	0.14	5.29	n.d.
'Golden Eye' (improved)	17/1/2020	n.d	0.11	5.83	0.33
'Oracle' a.k.a 'Golden Eye v. 3'	10/2/2020	n.d.	0.15	5.95	0.13
'Golden Grape'	22/1/2020	6.01	n.d.	n.d.	n.d.
'Golden Light'	23/1/2020	3.44	0.13	n.d.	0.14
'Laxton Lad'	22/1/2020	2.83	n.d.	n.d.	n.d.
'Laxton Lass'	22/1/2020	4.44	n.d.	n.d.	n.d.
'Mini Olga'	22/1/2020	6.65	0.06	n.d.	n.d.
'Moonglow '	17/1/2020	4.88	n.d.	n.d.	n.d.
'Moonglow'	10/2/2020	4.23	0.12	n.d.	0.38
'Olga's Round Golden Chicken Egg'	22/1/2020	4.32	n.d.	n.d.	n.d.
'Olga's Round Golden Chicken Egg'	10/2/2020	4.10	0.05	n.d.	0.15
'Orange Cream'	22/1/2020	1.12	0.06	n.d.	0.10
'Orange Oxheart' (ex Diane Shenkel)	17/1/2020	4.86	n.d.	n.d.	n.d.
'Orange Roma'	23/1/2020	4.62	0.03	n.d.	0.14
'Paradise Tomato' (a.k.a 'Orange Fleshed Purple Smudge')	17/1/2020	5.42	n.d.	n.d.	n.d.
'Paradise Tomato' (larger tomato without smudge)	17/1/2020	5.19	n.d.	n.d.	n.d.
'Small Sweet Orange'	22/1/2020	3.69	n.d.	n.d.	0.14
'Small Sweet Orange v. 3'	22/1/2020	4.68	0.04	n.d.	n.d.

The carotenoid concentrations shown in Table 1 are generally comparable to results from previous years (see Appendix 2).

Cultivars 'Beachman's Tomato', 'Blazing Beauty', 'Bob Logan Tomato', 'Orange Cream', 'Orange Oxheart', 'Paradise Tomato', 'Laxton Lad', and 'Laxton Lass' samples have not been analysed prior to this year. No comment can therefore be made regarding their carotenoid content compared to previous years.

β-carotene was only detected in samples in which tetra-cis (TC)-lycopene was not detected. This is to be expected, as *β*-carotene production requires all-trans (AT)-lycopene. AT-lycopene is generated from TC-lycopene by the carotenoid isomerase enzyme (CRTISO). Orange tomatoes which contain TC-lycopene as the main pigment have a non-functional CRTISO, which prohibits the formation of AT-lycopene.

Unexpectedly, some samples that contained TC-lycopene also appeared to contain small amounts of AT-lycopene and lutein (a derivative of AT-lycopene). Hypotheses for the presence of AT-lycopene in these samples may be:

- Another carotenoid with the same spectra and retention time as AT-lycopene being present (see Appendix 3);
- The CRTISO enzyme not being completely non-functional in these samples;
- Another enzyme capable of performing the transformation of TC- to AT-lycopene (albeit at a reduced capacity) being present.
- TC- to AT-lycopene conversion occurring as a result of non-enzymatic chemical reactions, either during fruit growth prior to harvesting or as a result of sample preparation (Saini *et al.* 2020)

β-carotene and lutein are both synthesised from AT-lycopene following reactions that occur via lycopene B-cyclase (LCYB) and lycopene E-cyclase (LCYE), respectively (Yuan et al. 2015) (see Appendix 4). The presence of lutein in samples containing AT-lycopene is therefore to be expected. Possible explanations for the absence of *β*-carotene in these samples could be that it is genuinely not being produced in these fruit (non-functional CRTISO) or is present at levels below our detection limit.

It is worth noting that the AT-lycopene concentrations in these samples are low, with concentrations < 0.4 mg/100 g fresh weight of fruit.

HPLC-DAD showed UV peaks consistent with the presence of several unknown carotenoids; further identification and quantitation was beyond the scope of this project. Analyses of these unknown carotenoid compounds would require the purchase of standards and further optimisation of the current LC method to improve compound retention and separation.

The polyphenols detected in the tomato fruit samples were chlorogenic acid (CGA), crypto-CGA, kaempferol 3-*O*-rutinoside (k-rut), and quercetin 3-*O*-rutinoside (q-rut). Three unknown polyphenols were also detected. Unknowns 1, 2, and 3 were tentatively identified as (*E*)-caffeoyl 3-*O*-glucoside, quercetin 3-xylosylrutinoside, and naringenin chalcone respectively. Concentrations of detected and identified polyphenol compounds are reported in Table 2.

Table 2. Concentrations (mg/100g fresh weight (FW)) of polyphenols in supplied tomato cultivars detected by high performance liquid chromatography mass spectrometry (HPLC-MS). "n.d." denotes compounds that were not detected in the sample. Detected compounds were chlorogenic acid (CGA), crypto-chlorogenic acid (crypto-CGA), kaempferol-3-O-rutinoside (k-rut), quercetin-3-rutinoside (q-rut), and three unknown peaks tentatively identified as (E)-caffeoyl 3-glucoside, quercetin 3-xylosylrutinoside, and naringenin chalcone (unknown 1, 2, and 3 respectively). Two separate samples were received for 'Moonglow' and 'Olga's Round Golden Chicken Egg' cultivars. These were analysed as separate samples.

Sample	Received	CGA	crypto-CGA	k-rut	q-rut	unknown 1	unknown 2	unknown 3
'Amish Yellowish Orange Oxheart'	22/1/2020	2.4	1.1	n.d.	0.7	45.8	0.6	n.d.
'B'mato'	17/1/2020	0.3	0.6	n.d.	0.5	11.0	0.5	0.3
'Golden Bell' (Beachman's)	23/1/2020	13.8	2.4	n.d.	0.7	63.6	0.3	n.d.
'Blazing Beauty'	17/1/2020	1.3	0.9	n.d.	0.8	23.2	0.2	3.0
'Bob Logan Tomato'	17/1/2020	1.5	1.2	n.d.	0.2	32.1	0.3	n.d.
'Golden Eye (original)'	17/1/2020	54.9	1.7	0.5	9.0	48.4	2.1	0.3
'Golden Eye (improved)'	17/1/2020	7.2	3.1	0.2	3.7	75.1	1.7	n.d.
'Oracle' a.k.a 'Golden Eye v. 3'	10/2/2020	11.7	3.4	n.d.	2.8	51.9	0.9	0.5
'Golden Grape'	22/1/2020	2.3	2.5	0.3	3.3	24.3	0.4	7.7
'Golden Light'	23/1/2020	2.6	1.6	n.d.	0.4	22.3	0.6	n.d.
'Laxton Lad'	22/1/2020	0.8	0.9	n.d.	0.8	45.4	0.4	n.d.
'Laxton Lass'	22/1/2020	0.8	0.9	n.d.	0.5	49.1	0.3	n.d.
'Mini Olga'	22/1/2020	1.7	2.7	n.d.	1.0	65.9	0.5	0.3
'Moonglow'	17/1/2020	1.8	1.4	n.d.	0.8	24.3	0.2	0.9
'Moonglow'	10/2/2020	1.0	1.7	n.d.	1.4	41.9	1.1	0.1
'Olga's Round Golden Chicken Egg'	22/1/2020	1.0	1.1	n.d.	0.3	33.4	0.2	0.6
'Olga's Round Golden Chicken Egg'	10/2/2020	1.2	1.4	n.d.	0.7	43.9	0.3	0.1
'Orange Cream'	22/1/2020	1.9	1.6	n.d.	1.4	65.5	0.8	n.d.
'Orange Oxheart (ex Diane Shenkel)'	17/1/2020	1.2	1.4	n.d.	0.5	17.5	0.3	3.4
'Orange Roma'	23/1/2020	2.3	2.3	n.d.	0.2	30.1	0.4	n.d.

Sample	Received	CGA	crypto-CGA	k-rut	q-rut	unknown 1	unknown 2	unknown 3
'Paradise Tomato' a.k.a. 'Orange Fleshed Purple smudge'	17/1/2020	0.5	0.8	n.d.	0.5	17.9	0.3	n.d.
'Paradise Tomato' (larger tomato without smudge)	17/1/2020	0.7	1.1	n.d.	0.2	27.2	0.2	n.d.
'Small Sweet Orange'	22/1/2020	6.9	4.1	0.5	5.6	34.2	0.6	2.3
'Small Sweet Orange v. 3'	22/1/2020	1.3	1.1	0.2	1.1	42.0	0.3	0.9

Unknown 1 was generally the compound with the highest concentration in the tomato fruit samples, and was tentatively identified as either (E)-caffeoyl 3- (or 4)-glucoside. This compound peak had a retention time of 1.58 min and a main $[M\text{-}H]^-$ with a mass to charge ratio (*m/z*) of 341.0871. This mass to charge ratio is consistent with either (E)-caffeoyl 3- or 4-glucoside. A fragment ion at *m/z* 179.0336 was also present, which was assigned to the caffeic acid fragment from this compound.

Unknown 2 eluted at 4.04 min with a main mass fragment of *m/z* 741.1853. This was tentatively identified as quercetin 3-3'-xylosylrutinoside, consistent with its *m/z* value and an elution time close to that of other quercetin based compounds. This compound is also known to be present in tomatoes.

Unknown 3 had a retention time of 7.11 min with *m/z* 271.0592 as the major peak. This mass is consistent with naringenin chalcone.

These three tentative identifications are also based on 2019 results for sample set SC54. The difference in retention time of these compounds is due to different columns being used for the two analyses. The retention time shift is also seen when comparing retention times of standard compounds.

The compounds, caffeic acid, catechin, *epi*-catechin, cyanidin 3-glucoside, procyanidin B1 and B2, *p*-coumaroylquinic acid, quercetin, quercetin 3-galactoside, quercetin 3-glucoside, and quercetin 3-rhamnoside, were also screened for but were not detected in any sample.

A comparison summary of 2019 and 2020 results is presented in Appendix 5.

Qualifying statement

The results given in this report apply only to the samples provided to PFR, which may or may not be representative of all examples of the tomato variety.

4 References

Saini RK, Bekhit AED, Roohinejad S, Rengasamy KRR, Keum YS 2020. Chemical Stability of Lycopene in Processed Products: A Review of the Effects of Processing Methods and Modern Preservation Strategies. J. Agric. Food Chem. 68, 3, 712-726.

Yuan H, Zhang J, Nageswaran D, Li L. 2015. Carotenoid metabolism and regulation in horticultural crops. Horticulture Research 2: 15036.

Appendix 1

Table 3. Detected compounds and their associated CAS numbers. Compounds that were not detected in any sample are not listed.

Compound	CAS number
All-trans-lycopene	502-65-8
Tetra-cis-lycopene	2361-24-2
Beta-carotene	7235-40-7
Lutein	127-40-2
Chlorogenic acid	327-97-9
Crypto-chlorogenic acid	905-99-7
Kaempferol-3-O-rutinoside	17650-84-9
trans-4-p-coumaroyl-quinic acid	1108200-72-1
Quercetin-3-glucoside	482-35-9
Quercetin-3-rutinoside	153-18-4
(E)-caffeoyl 3-glucoside	24959-81-7
Quercetin 3-xylosylrutinoside	129235-39-8
Naringenin chalcone	73692-50-9

Appendix 2. Carotenoid content of tomato samples from 2015 – 2020

Table 4. Summary of the concentrations (mg/100 g FW) of tetra-cis lycopene (TClyc), lutein (lut), beta-carotene (B-caro), and all-trans lycopene (ATlyc) measured in tomato fruit samples from Heritage Food Crops. Varieties analysed only once or not analysed in 2020 are not included. Concentrations of all four measured compounds vary to some extent between years.

		2015/SC13				2016/TK109				2018/SC44				2019/SC54				2020/SC67			
Sample	Sample #	TClyc	Lut	B-caro	ATlyc	TClyc	Lut	B-caro	ATlyc	TClyc	Lut	B-caro	ATlyc	TClyc	Lut	B-caro	ATlyc	TClyc	Lut	B-caro	ATlyc
'Amish Yellowish Orange Oxheart'		8.21	n.d.	n.d.	0.04	4.36	0.04	3.24	0.14	3.28	0.04	n.d.	0.03	4.57	0.03	n.d.	0.06	7.05	n.d.	n.d.	n.d.
'B'mato'														10.24	n.d.	n.d.	n.d.	3.65	n.d.	n.d.	n.d.
'Golden Eye'						n.d.	0.20	15.25	n.d.					n.d.	0.11	6.28	n.d.	n.d.	0.14	5.29	n.d.
'Golden Eye Improved'																		n.d.	0.11	5.83	0.33
'Oracle' a.k.a 'Golden Eye version 3'																		n.d.	0.15	5.95	0.13
'Golden Grape'		2.59	0.05	0.81	0.07									5.06	0.12	n.d.	0.10	6.01	n.d.	n.d.	n.d.
'Golden Light' a.k.a 'Orange Teardrop v. 2'										4.29	0.06	3.50	0.20	10.13	0.08	n.d.	0.20	3.44	0.13	n.d.	0.14
'Mini Olga'														7.60	0.03	n.d.	0.07	6.65	0.06	n.d.	n.d.
'Moonglow' [17/1/2020]	SC67.2	5.38	n.d.	n.d.	0.02	3.71	n.d.	n.d.	n.d.	3.46	n.d.	n.d.	n.d.	4.98	0.02	n.d.	n.d.	4.88	n.d.	n.d.	n.d.
'Moonglow' [10/2/2020]	SC67.24																	4.23	0.12	n.d.	0.38
'Olga's Round Golden Chicken Egg' [22/1/2020]	SC67.18					2.93	0.07	n.d.	0.03	2.61	0.03	n.d.	0.06	5.13	0.03	n.d.	n.d.	4.32	n.d.	n.d.	n.d.
'Olga's Round Golden Chicken Egg' [10/2/2020]	SC67.23																	4.10	0.05	n.d.	0.15
'Orange Roma'		6.92	0.02	n.d.	0.08									4.72	0.07	n.d.	0.09	4.62	0.03	n.d.	0.14
'Orange Fleshed Purple Smudge'		6.99	0.03	n.d.	0.04									11.40	0.03	n.d.	0.17				
'Paradise Tomato' (aka Orange Fleshed Purple Smudge)	SC67.5																	5.42	n.d.	n.d.	n.d.
'Paradise Tomato' (larger tomato without smudge)	SC67.6																	5.19	n.d.	n.d.	n.d.
'Small Sweet Orange'		1.73	0.12	0.87	0.10					3.89	0.05	n.d.	n.d.	6.10	0.08	n.d.	0.04	3.69	n.d.	n.d.	0.14
'Small Sweet Orange' (version 2)														8.67	0.05	n.d.	0.04				
'Small Sweet Orange' (Version 3)														6.98	0.04	n.d.	n.d.	4.68	0.04	n.d.	n.d.

'Beachman's Tomato', 'Blazing Beauty', 'Bob Logan Tomato', 'Orange Cream', 'Orange Oxheart', 'Laxton Lad', and 'Laxton Lass' samples had not been analysed prior to this year, so are not included in this table.

The concentration of all four measured carotenoids varies year to year, although lutein and AT-lycopene concentrations in these samples typically remain low.

‘B’mato’, ‘Golden Light’, ‘Small Sweet Orange’, and ‘Small Sweet Orange v. 3’ all had TC-lycopene concentrations lower than those from 2019. The concentration in ‘Small Sweet Orange’ was, however, similar to that measured in 2018 and higher than that from 2015. Data from other years were not available for ‘B’mato’, ‘Golden Light’, or ‘Small Sweet Orange v. 3’.

The concentration of TC-lycopene in ‘Amish Yellowish Orange Oxheart’ was similar to that seen in 2015 and higher than concentrations seen in 2016, 2018, and 2019.

Not knowing the cultivation methods involved, it is not possible to definitively say what the cause of the variation in carotenoid concentration between years is. A possible explanation may include one or a combination of the following:

- Number of fruit per sample tested affecting balance of skin and flesh tissues
- Environmental factors, e.g. sunshine hours, rain volume, temperature
- Genetic factors, i.e. fruit do not come from genetically identical plants each year, possibility of cross pollination between varieties
- Soil nutrient levels.

Appendix 3. All-trans-lycopene spectra

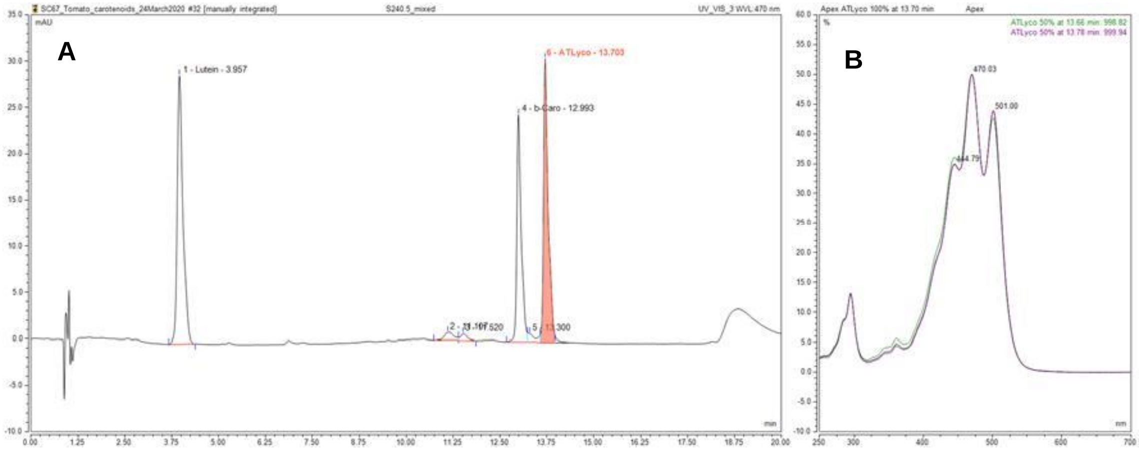

Figure 1 (A) Example chromatogram of carotenoid standard with AT-lycopene highlighted. (B) bsorbance spectra of the authentic standard of AT-lycopene.

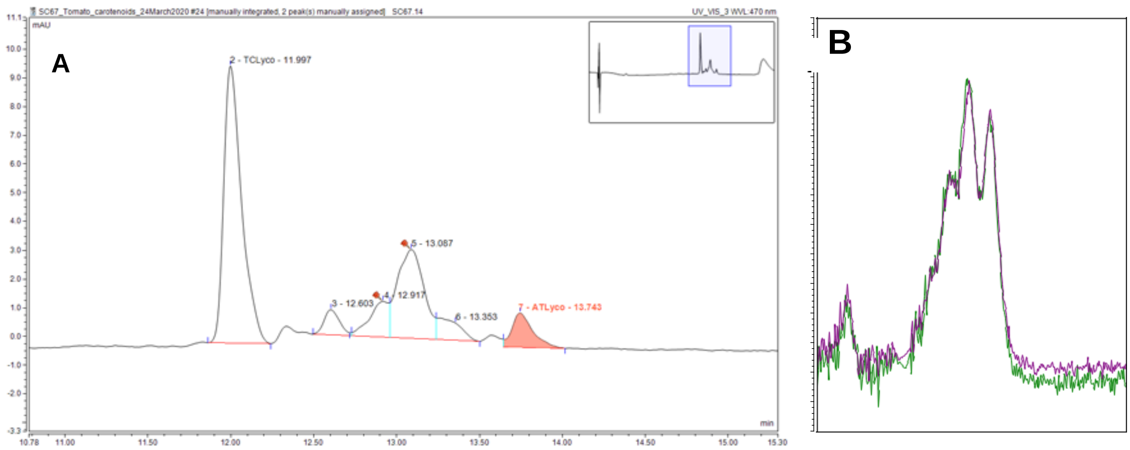

Figure 2 (A) Example sample chromatogram showing retention time of 11 – 15 mins. TC and AT-lycopene peaks are visible. (B) Absorbance spectra of peak identified as AT-lycopene in samples.

Appendix 4. Carotenoid metabolic pathway

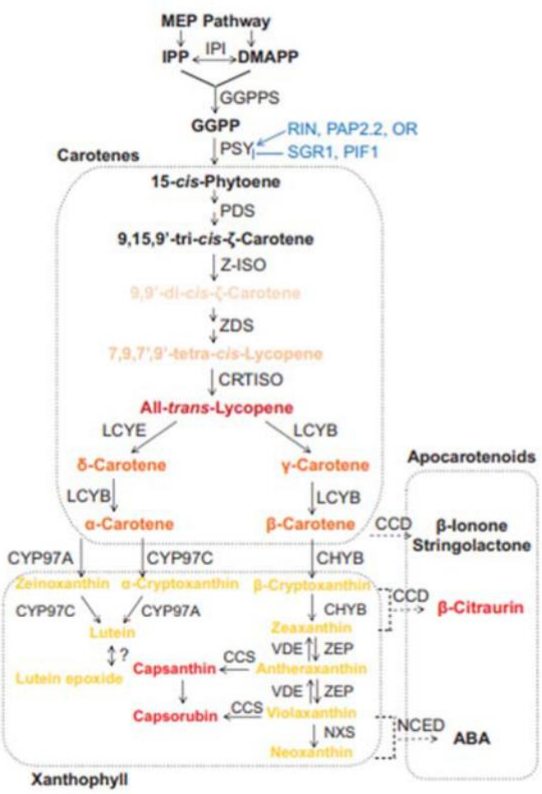

Figure 1. General carotenoid metabolic pathway in horticultural crops. PSY catalyzes the first committed condensation step from GGPP to produce the first C40 carotene, phytoene. Following several desaturation and isomerization steps, lycopene is produced. The next cyclization yields the α-carotene and β-carotene branches. A wide range of carotenoids are degraded by CCDs or NCEDs to produce apocarotenoids. IPP, isopentenyl diphosphate; DMAPP, dimethylallyl diphosphate; GGPP, geranylgeranyl diphosphate; IPI, isopentenyl diphosphate isomerase; GGPPS, GGPP synthase; PSY, phytoene synthase; PDS, phytoene desaturase; Z-ISO, ζ-carotene isomerase; ZDS, ζ-carotene desaturase; CRTISO, carotenoid isomerase; LCYE, lycopene ε-cyclase; LCYB, lycopene β-cyclase; CHYB, β-carotene hydroxylase; CYP97C, cytochrome P450-type monooxygenase 97C; ZEP, zeaxanthin epoxidase; VDE, violaxanthin de-epoxidase; CCS, capsanthin-capsorubin synthase; NXS, neoxanthin synthase; CCD, carotenoid cleavage dioxygenase; NCED, 9-*cis*-epoxycarotenoid dioxygenase. Metabolites are bolded and colored according to their compound colors, whereas black indicates no color. Enzymes and regulators are not bolded. Solid arrows indicate biosynthesis and dashed arrows indicate degradation PSY regulators are colored in blue. Dotted rectangles separate different groups of carotenoids.

Carotenoid synthesis pathway from Yuan et al. 2015. Steps of particular interest are the transformation of tetra-cis lycopene to all-trans lycopene by the carotenoid isomerase enzyme (CRTISO), followed by the branching of the pathway to synthesise either lutein or beta-carotene via pathways involving the lycopene E-cyclase and lycopene B-cyclase enzymes, respectively.

Appendix 5. 2019 and 2020 polyphenol concentrations

Table 5. Summary of the concentration (mg/100 g FW) of polyphenols in tomato fruit samples from Heritage Food Crops. Varieties not analysed in previous years and varieties analysed previously but not in 2020 are not included. Concentrations of all measured compounds vary to some extent between years. "n.d." denotes compounds that were not detected in the sample. "n.c." is where a concentration was not calculated due to being outside of (above) the calibration range for that compound. Detected compounds were chlorogenic acid (CGA), crypto-chlorogenic acid (crypto-CGA), kaempferol-3-O-rutinoside (K-rut), quercetin-3-rutinoside (Q- rut), and three unknown peaks tentatively identified as (E)-caffeoyl 3-glucoside, quercetin 3-xylosylrutinoside, and naringenin chalcone (unknown 1, 2, and 3 respectively).

			mg/100 g FW							
Sample	Sample #	Year	CGA	Crypto-CGA	K-rut	Q-rut	p-CouQA	Unknown 1	Unknown 2	Unknown 3
'Amish Yellow Orange Oxheart'	SC54.4	2019	1.5	1.0	n.d.	1.0	n.d.	21.5	0.5	n.d.
'Amish Yellowish Orange Oxheart'	SC67.10	2020	2.4	1.1	n.d.	0.7	n.d.	45.8	0.6	n.d.
'B'mato'	SC54.28	2019	1.0	1.3	n.d.	0.5	n.d.	26.7	0.8	3.5
'B'mato'	SC67.1	2020	1.3	0.9	n.d.	0.8	n.d.	23.2	0.2	3.0
'Golden Eye'	SC54.20	2019	17.6	0.6	0.2	7.5	n.d.	n.c.	2.9	n.d.
'Golden Eye (original)'	SC67.8	2020	54.9	1.7	0.5	9.0	n.d.	48.4	2.1	0.3
'Golden Eye (improved)'	SC67.9	2020	7.2	3.1	0.2	3.7	n.d.	75.1	1.7	n.d.
'Oracle' a.k.a 'Golden Eye version 3'	SC67.25	2020	11.7	3.4	n.d.	2.8	n.d.	51.9	0.9	0.5
'Golden Grape'	SC54.7	2019	1.5	1.6	0.2	5.2	n.d.	30.5	0.7	9.5
'Golden Grape'	SC67.13	2020	2.3	2.5	0.3	3.3	n.d.	24.3	0.4	7.7
'Golden Light'	SC54.24	2019	0.7	0.8	n.d.	0.5	n.d.	17.7	1.1	n.d.
'Golden Light'	SC67.21	2020	2.6	1.6	n.d.	0.4	n.d.	22.3	0.6	n.d.
'Mini Olga'	SC54.3	2019	0.2	0.7	n.d.	0.5	n.d.	n.c.	n.d.	0.5
'Mini Olga'	SC67.16	2020	1.7	2.7	n.d.	1.0	n.d.	65.9	0.5	0.3
'Moonglow'	SC54.1	2019	0.2	0.5	n.d.	0.5	n.d.	13.2	0.3	1.1
'Moonglow' [17/1/2020]	SC67.2	2020	1.8	1.4	n.d.	0.8	n.d.	24.3	0.2	0.9
'Moonglow' [10/2/2020]	SC67.24	2020	1.0	1.7	n.d.	1.4	n.d.	41.9	1.1	0.1
'Olga's Round Golden Chicken Egg'	SC54.11	2019	0.7	0.7	n.d.	0.5	n.d.	16.9	0.3	2.4
'Olga's Round Golden Chicken Egg' [22/1/2020]	SC67.18	2020	1.0	1.1	n.d.	0.3	n.d.	33.4	0.2	0.6
'Olga's Round Golden Chicken Egg' [10/2/2020]	SC67.23	2020	1.2	1.4	n.d.	0.7	n.d.	43.9	0.3	0.1
'Orange Roma'	SC54.14	2019	0.7	0.8	n.d.	0.2	n.d.	19.7	0.1	n.d.

			mg/100 g FW							
Sample	**Sample #**	**Year**	**CGA**	**Crypto-CGA**	**K-rut**	**Q-rut**	**p-CouQA**	**Unknown 1**	**Unknown 2**	**Unknown 3**
'Orange Roma'	SC67.20	2020	2.3	2.3	n.d.	0.2	n.d.	30.1	0.4	n.d.
'Orange Fleshed Purple Smudge'	SC54.19	2019	0.2	0.4	n.d.	0.2	n.d.	16.2	0.2	n.d.
'Paradise Tomato' aka 'Orange Fleshed Purple Smudge'	SC67.5	2020	0.5	0.8	n.d.	0.5	n.d.	17.9	0.3	n.d.
'Paradise Tomato' (larger tomato without smudge)	SC67.6	2020	0.7	1.1	n.d.	0.2	n.d.	27.2	0.2	n.d.
'Small Sweet Orange'	SC54.16	2019	3.2	2.0	0.2	4.4	n.d.	n.c.	0.6	1.8
'Small Sweet Orange'	SC67.14	2020	6.9	4.1	0.5	5.6	n.d.	34.2	0.6	2.3
'Small Sweet Orange (version 3)'	SC54.18	2019	1.2	1.1	0.2	1.2	0.0	n.c.	0.2	0.7
'Small Sweet Orange (version 3)'	SC67.15	2020	1.3	1.1	0.2	1.1	n.d.	42.0	0.3	0.9

Cultivars 'Golden Bell', 'Blazing Beauty', 'Bob Logan Tomato', 'Orange Cream', 'Orange Oxheart', 'Laxton Lad', and 'Laxton Lass' samples had not been analysed prior to this year, so are therefore not included in this table.

Most samples show at least some variation in concentration between years across all detected polyphenols. 'Small Sweet Orange (version 3)' and 'B'mato' appears to have the most consistency between the two years. Possible explanations for this variation are the same as stated for carotenoids in Appendix 2.

Confidential report for:

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