

Carotenoid and polyphenol compounds in tomatoes

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Plant & Food Research: Palmerston North

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1 BACKGROUND

The Heritage Food Crops Research Trust are interested in understanding the health benefits of tomatoes. The aim of the present investigation was to determine the polyphenol and carotenoid contents of twenty-eight tomato varieties.

2 MATERIALS AND METHODS

Twenty-eight varieties of tomato provided by Mark Christensen, Heritage Food Crops, were stored at -18°C from when they arrived at PFR, Palmerston North until analysis.

Lab Reference: SC54

To obtain a representative sample for chemical analysis, all, or a portion of the frozen tomato fruit provided was homogenised with dry ice. A subsample of 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
- Quercetin 3-xylosylrutinoside – quantified as quercetin 3-rutinoside equivalents
- Crypto-chlorogenic acid – quantified as chlorogenic acid equivalents
- Naringenin – quantified as trans-4-*p*-coumaroyl quinic acid equivalents
- (*E*)-caffeoyl 3- or 4-glucoside – quantified as caffeic acid equivalents.

The quantitative results are expressed on a per weight basis (mg/100 g fresh weight (FW)).

A list of detected compounds and their associated CAS numbers can be found in Appendix 1.

3 RESULTS

Carotenoid concentrations of the 28 tomato varieties submitted for analysis are shown in Table 1. Although all tomatoes received were “orange” or “yellow”, the majority of them appeared to contain all-trans (AT) lycopene, albeit in small quantities.

Table 1. Concentrations of known carotenoid compounds (mg/100 g fresh weight (FW)) 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.

| Variety | AT-lycopene | TC-lycopene | Lutein | β -carotene |
|-----------------------------------|-------------|-------------|--------|-------------------|
| 'Moonglow' | n.d. | 4.98 | 0.02 | n.d. |
| 'Mouse Tomato' | 0.05 | 3.50 | 0.06 | n.d. |
| 'Mini Olga' | 0.07 | 7.60 | 0.03 | n.d. |
| 'Amish Yellow Orange Oxheart' | 0.06 | 4.57 | 0.03 | n.d. |
| 'Amish Golden' 2019 new selection | 0.08 | 3.85 | 0.03 | n.d. |
| 'Alice Brewer' | 0.05 | 4.37 | 0.03 | n.d. |
| 'Golden Grape' | 0.10 | 5.06 | 0.12 | n.d. |
| 'Tangerine' | 0.02 | 4.83 | 0.02 | n.d. |
| 'Tangella' | 0.28 | 3.83 | 0.12 | n.d. |
| 'Orange Beefsteak' | 0.08 | 3.61 | 0.04 | n.d. |
| 'Olga's Round Golden Chicken Egg' | n.d. | 5.13 | 0.03 | n.d. |
| 'Mini Orange' | 0.09 | 3.49 | 0.08 | n.d. |
| 'Golden Green' | 0.03 | 4.48 | 0.04 | n.d. |
| 'Orange Roma' | 0.09 | 4.72 | 0.07 | n.d. |
| 'Orange Crimea' | 0.04 | 9.92 | 0.02 | n.d. |
| 'Small Sweet Orange (original)' | 0.04 | 6.10 | 0.08 | n.d. |
| 'Small Sweet Orange (Version 2)' | 0.04 | 8.67 | 0.05 | n.d. |
| 'Small Sweet Orange (Version 3)' | n.d. | 6.98 | 0.04 | n.d. |
| 'Orange Fleshed Purple Smudge' | 0.17 | 11.40 | 0.03 | n.d. |
| 'Golden Eye' | n.d. | n.d. | 0.11 | 6.28 |
| 'Barnes Mountain Orange' | 0.08 | 12.34 | n.d. | n.d. |
| 'Ilse's Orange Latvian' | 0.09 | 5.85 | 0.04 | n.d. |
| 'Orange Strawberry' | 0.15 | 11.86 | 0.04 | n.d. |
| 'Golden Light' | 0.20 | 10.13 | 0.05 | n.d. |
| 'Persimmon' | 0.13 | 8.44 | 0.03 | n.d. |
| 'Hurma Ukrainian' | 0.17 | 6.80 | 0.05 | n.d. |
| 'Orange Teardrop' | 0.05 | 7.01 | 0.04 | n.d. |
| 'Bmato' | n.d. | 10.24 | n.d. | n.d. |

A table comparing this year's results with revised results from previous years can be found in Appendix 2.

Table 2. Concentrations of known polyphenols (mg/100 g fresh weight (FW)) in tomato varieties measured by high performance liquid chromatography mass spectrometry (HPLC-MS). Zero values indicate compounds with concentrations < 0.00 mg/100 g. "n.d." denotes compounds that were not detected in the sample. "n.c." is "not calculated" and marks samples where the detected peak area was outside that of the calibration zone. Detected compounds were chlorogenic acid (CGA), cryptochlorogenic acid (crypto-CGA), kaempferol-3-O-rutinoside, trans-4-p-coumaroyl quinic acid (p-CQA), quercetin-3-glucoside (q-glu), quercetin-3-rutinoside (q-rut) and three unknown compounds. Putative identifications for unknowns 1, 2 and 3 are (*E*)-caffeoyl 3 or 4-glucoside, quercetin 3-xylosylrutinoside) and naringenin chalcone respectively.

| Variety | CGA | crypto-CGA | k-rut | p-CQA | q-glu | q-rut | unkno wn 1 | unkno wn 2 | unkno wn 3 |
|-----------------------------------|------|------------|-------|-------|-------|-------|------------|------------|------------|
| 'Moonglow' | 0.2 | 0.5 | n.d. | n.d. | n.d. | 0.5 | 13.22 | 0.27 | 1.05 |
| 'Mouse Tomato' | 0.9 | 0.9 | n.d. | n.d. | n.d. | 0.2 | 26.53 | n.d. | n.d. |
| 'Mini Olga' | 0.2 | 0.7 | n.d. | n.d. | n.d. | 0.5 | n.c. | n.d. | 0.54 |
| 'Amish Yellow Orange Oxheart' | 1.5 | 1.0 | n.d. | n.d. | 0.0 | 1.0 | 21.50 | 0.45 | n.d. |
| 'Amish Golden' 2019 new selection | 0.5 | 0.6 | n.d. | n.d. | 0.0 | 0.5 | 22.15 | 0.11 | n.d. |
| 'Alice Brewer' | 0.5 | 0.5 | n.d. | n.d. | n.d. | 0.7 | 14.51 | 0.13 | 0.98 |
| 'Golden Grape' | 1.5 | 1.6 | 0.2 | n.d. | n.d. | 5.2 | 30.52 | 0.71 | 9.51 |
| 'Tangerine' | 0.5 | 0.5 | n.d. | n.d. | n.d. | 0.5 | 8.90 | 0.27 | 1.45 |
| 'Tangella' | 1.2 | 1.7 | n.d. | n.d. | n.d. | 1.7 | n.c. | 0.81 | 0.26 |
| 'Orange Beefsteak' | 0.7 | 0.9 | n.d. | n.d. | n.d. | 1.0 | 38.28 | 0.25 | 0.70 |
| 'Olga's Round Golden Chicken Egg' | 0.7 | 0.7 | n.d. | n.d. | n.d. | 0.5 | 16.87 | 0.28 | 2.37 |
| 'Mini Orange' | 0.5 | 0.9 | n.d. | n.d. | n.d. | 1.0 | 45.36 | 0.64 | 0.56 |
| 'Golden Green' | 1.0 | 0.9 | n.d. | n.d. | n.d. | 0.7 | 25.16 | 0.39 | 1.00 |
| 'Orange Roma' | 0.7 | 0.8 | n.d. | n.d. | n.d. | 0.2 | 19.74 | 0.10 | n.d. |
| 'Orange Crimea' | 0.7 | 0.8 | n.d. | n.d. | 0.0 | 0.5 | 17.97 | 0.16 | 1.94 |
| 'Small Sweet Orange (original)' | 3.2 | 2.0 | 0.2 | n.d. | n.d. | 4.4 | n.c. | 0.56 | 1.78 |
| 'Small Sweet Orange (Version 2)' | 2.2 | 1.2 | 0.2 | 0.2 | n.d. | 2.9 | 45.06 | 0.59 | 1.65 |
| 'Small Sweet Orange (Version 3)' | 1.2 | 1.1 | 0.2 | n.d. | n.d. | 1.2 | n.c. | 0.24 | 0.67 |
| 'Orange Fleshed Purple Smudge' | 0.2 | 0.4 | n.d. | n.d. | 0.0 | 0.2 | 16.19 | 0.19 | n.d. |
| 'Golden Eye' | 17.6 | 0.6 | 0.2 | n.d. | n.d. | 7.5 | n.c. | 2.93 | n.d. |
| 'Barnes Mountain Orange' | 0.7 | 0.9 | n.d. | n.d. | 0.0 | 0.0 | 24.83 | 0.16 | n.d. |
| 'Ilse's Orange Latvian' | 0.5 | 0.7 | n.d. | n.d. | n.d. | 0.2 | n.c. | 0.55 | n.d. |
| 'Orange Strawberry' | 0.2 | 0.6 | 0.0 | n.d. | 0.0 | 2.1 | 9.69 | 0.71 | 0.69 |

| | | | | | | | | | |
|-------------------|-----|-----|------|------|-----|-----|-------|----------|----------|
| 'Golden Light' | 0.7 | 0.8 | n.d. | n.d. | n.d | 0.5 | 17.70 | 1.0 6 | n.d. |
| 'Persimmon' | 1.9 | 1.3 | n.d. | n.d. | n.d | 0.2 | 37.25 | 0.0 3 | n.d. |
| 'Hurma Ukrainian' | 0.2 | 0.6 | n.d. | n.d. | 0.0 | 1.6 | 12.85 | 0.6 9 | 0.7 6 |
| 'Orange Teardrop' | 0.2 | 0.7 | n.d. | n.d. | n.d | 0.2 | 14.23 | 0.6 6 | n.d. |
| 'B'mato' | 1.0 | 1.3 | n.d. | n.d. | n.d | 0.5 | 26.68 | 0.7 7 | 3.4 6 |

Concentrations of polyphenol compounds detected in the 28 tomato varieties submitted for analysis are shown in Table 2. Unknown 1, thought to be (*E*)-caffeoyl 3 or 4-glucoside, was generally the most abundant polyphenol detected. Caffeic acid, catechin, epicatechin, cyanidin 3-glucoside, procyanidin B1 and B2, quercetin, quercetin 3-galactoside and quercetin 3-rhamnoside were also screened for, but were not detected in any sample.

The tentative identifications for the three unknown phenolic metabolites were determined as follows:

Unknown 1 had a retention time of 3.81 minutes and a main [M-H]⁻ at *m/z* 341.0877. This mass is consistent with (*E*)-caffeoyl 3 or 4-glucoside. A fragment peak at *m/z* 179.0336 was also present, which could be the caffeic acid fragment from this compound.

Unknown 2 eluted at 9.26 minutes, with a main [M-H]⁻ at *m/z* 741.1860. This was tentatively identified as quercetin 3-xylosylrutinoside, because of the consistent *m/z* and an elution time close to that of other quercetin-based compounds.

Unknown 3 had a retention time of 13.18 minutes, with *m/z* 271.0610 as the major peak. This mass is consistent with naringenin chalcone. Naringenin chalcone was chosen over naringenin for identification because when a sample containing this peak ('Moonglow') was run alongside an authentic naringenin standard in a separate analysis, the retention time of unknown 3 was 0.2 min later than that of the standard peak.

3.1 Qualifying statement

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

APPENDIX 1

Table A1 Detected compounds from tomato samples and their associated CAS numbers.

| 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

Table A2. Summary of carotenoid concentrations (mg/100 g fresh weight (FW)) in cultivars analysed from 2015, 2016, 2018 and 2019. Variation between years may be due to uncontrolled season variation or differences in the amount of fruit sampled.

| variety | sample | SC13/2015 | | | | TK109/2016 | | | | SC44/2018 | | | | SC54/2019 | | | |
|----------------------------------|---------|-----------|------|--------|--------|------------|------|--------|--------|-----------|------|--------|--------|-----------|------|--------|--------|
| | | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc |
| 'Alfred' | | | | | | | | | | n.d. | 0.12 | 1.42 | 4.02 | | | | |
| 'Alice Brewer' | MB63.12 | 1.55 | 0.02 | n.d. | n.d. | | | | | | | | | 4.37 | 0.03 | n.d. | 0.05 |
| 'Alice Brewer' | MB63.41 | 3.82 | 0.03 | n.d. | n.d. | | | | | | | | | | | | |
| 'Alice Brewer (red)' | | n.d. | 0.18 | 1.01 | 6.19 | | | | | | | | | | | | |
| 'Amana Orange' | | 5.04 | 0.06 | n.d. | 0.01 | | | | | | | | | | | | |
| 'Amber Coloured' | | n.d. | 0.18 | 0.19 | 0.06 | | | | | | | | | | | | |
| 'Amish Golden' 2019 selection | | | | | | | | | | | | | | 3.85 | 0.03 | n.d. | 0.08 |
| 'Amish Gold (orange)' | | n.d. | 0.09 | 4.89 | 0.19 | | | | | | | | | | | | |
| 'Amish Gold (red)' | | n.d. | 0.21 | 1.32 | 5.25 | | | | | | | | | | | | |
| 'Amish Orange Sherbert Heirloom' | | 5.36 | n.d. | n.d. | 0.02 | | | | | | | | | | | | |
| '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 |
| 'Aunt Gerties Gold' | | 5.73 | 0.05 | n.d. | 0.02 | | | | | | | | | | | | |

| variety | sample | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc |
|---|--------|--------|------|--------|--------|--------|-----|--------|--------|--------|------|--------|--------|--------|------|--------|--------|
| 'Barnes Mountain Orange' (also known as 'Barnes Mountain Yellow') | | 6.54 | n.d. | n.d. | 0.03 | | | | | | | | | 12.34 | n.d. | n.d. | 0.08 |
| 'Branscomb's Orange' | | n.d. | 0.07 | 2.93 | 1.36 | | | | | | | | | | | | |
| 'Big Orange' | | 6.14 | 0.03 | n.d. | 0.08 | | | | | | | | | | | | |
| 'Big Orange Stripe' | | n.d. | 0.14 | 1.13 | 0.12 | | | | | | | | | | | | |
| 'Big Yellow' | | 4.06 | 0.05 | n.d. | 0.03 | | | | | | | | | | | | |
| 'B'mato' | | | | | | | | | | | | | | 10.24 | n.d. | n.d. | n.d. |
| 'Brown's Yellow Giant' | | 3.57 | n.d. | n.d. | n.d. | | | | | | | | | | | | |
| 'Burbank (Koanga)' | | n.d. | 0.16 | 1.23 | 8.56 | | | | | | | | | | | | |
| 'Bursztyn' | | 3.34 | 0.03 | n.d. | 0.05 | | | | | | | | | | | | |
| 'Chuck's Yellow' | | 5.47 | n.d. | n.d. | 0.02 | | | | | | | | | | | | |
| 'Daniella' (red commercial hybrid) | | | | | | | | | | n.d. | 0.12 | 1.30 | 2.84 | | | | |
| 'Dark Orange Muscat (red)' | | n.d. | 0.18 | 1.30 | 5.48 | | | | | | | | | | | | |
| 'Dicoff's Yellow' | | n.d. | 0.13 | 0.76 | 1.94 | | | | | | | | | | | | |
| 'Djena Lees Golden Girl' | | 5.23 | 0.06 | n.d. | 0.04 | | | | | | | | | | | | |
| 'Earl of Edgecomb' | | 2.52 | 0.10 | n.d. | 0.03 | | | | | | | | | | | | |
| 'Elbe' | | 4.31 | 0.03 | n.d. | n.d. | | | | | | | | | | | | |
| 'Elfie (orange)' | | 4.94 | 0.05 | n.d. | 0.01 | | | | | | | | | | | | |
| 'Elfie(red)-orange' | | 3.46 | 0.07 | n.d. | n.d. | | | | | | | | | | | | |
| 'Faribo Goldheart' | | 4.90 | 0.02 | n.d. | n.d. | | | | | | | | | | | | |

| variety | sample | SC13/2015 | | | | TK109/2016 | | | | SC44/2018 | | | | SC54/2019 | | | |
|---|--------|-----------|------|--------|--------|------------|------|--------|--------|-----------|------|--------|--------|-----------|------|--------|--------|
| | | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc |
| 'Gary Ibsen's Gold' | | 4.00 | 0.03 | n.d. | n.d. | | | | | | | | | | | | |
| 'Gary's Golden Bear' | | 1.64 | 0.06 | n.d. | 0.01 | | | | | | | | | | | | |
| 'Gold Ball' | | n.d. | 0.13 | 0.32 | n.d. | | | | | | | | | | | | |
| 'Golden Eye' | | | | | | n.d. | 0.20 | 15.25 | n.d. | | | | | n.d. | 0.11 | 6.28 | n.d. |
| 'Golden Grape' | | 2.59 | 0.05 | 0.81 | 0.07 | | | | | | | | | 5.06 | 0.12 | n.d. | 0.10 |
| 'Golden Green' | | 7.12 | 0.05 | n.d. | n.d. | | | | | 3.34 | 0.04 | n.d. | 0.04 | 4.48 | 0.04 | n.d. | 0.03 |
| 'Golden Light' (selection of 'Orange Teardrop') | | | | | | | | | | 4.29 | 0.06 | n.d. | 0.20 | 10.13 | 0.08 | n.d. | 0.20 |
| 'Golden Ponderosa' | | n.d. | 0.20 | 0.37 | n.d. | | | | | | | | | | | | |
| 'Goldene Königin' | | n.d. | 0.16 | 0.57 | 0.18 | | | | | | | | | | | | |
| 'Gramma Climenhagen' | | n.d. | 0.12 | 0.19 | n.d. | | | | | | | | | | | | |
| 'Hawaiian Pineapple' | | 6.13 | 0.05 | n.d. | n.d. | | | | | | | | | | | | |
| 'Hawkes Bay Yellow (Koanga)' | | n.d. | 0.11 | 0.12 | n.d. | | | | | | | | | | | | |
| 'Homer Fike's Yellow Oxheart' | | 1.74 | 0.05 | n.d. | 0.01 | | | | | | | | | | | | |
| 'Hurma Ukrainian' | | 5.76 | 0.02 | n.d. | n.d. | | | | | | | | | 6.80 | 0.05 | n.d. | 0.17 |
| 'Ilse's Orange Latvian' (also known as 'Ilse's Yellow Latvian') | | 6.73 | 0.04 | n.d. | 0.05 | | | | | | | | | 5.85 | 0.04 | n.d. | 0.09 |
| 'Kellogs Breakfast' | | | | | | 3.42 | n.d. | 1.01 | n.d. | | | | | | | | |
| 'King's Gold (Koanga)' | | 3.02 | 0.03 | n.d. | n.d. | | | | | | | | | | | | |
| 'La Carotina' | | n.d. | 0.06 | 4.06 | 0.94 | | | | | | | | | | | | |
| 'Large Yellow Amish' | | 4.28 | 0.05 | n.d. | n.d. | | | | | | | | | | | | |
| 'Lemon Eye' | | | | | | n.d. | 0.15 | 0.37 | n.d. | | | | | | | | |
| <i>Lycopersicon macrocarpum lutea</i> | | n.d. | 0.17 | 0.06 | n.d. | | | | | | | | | | | | |
| Lyco Plus® | | n.d. | 0.10 | 0.53 | 5.98 | | | | | | | | | | | | |

| variety | sample | SC13/2015 | | | | TK109/2016 | | | | SC44/2018 | | | | SC54/2019 | | | |
|---|--------|-----------|------|--------|--------|------------|------|--------|--------|-----------|------|--------|--------|-----------|------|--------|--------|
| | | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc |
| 'M1 Tomato' | | n.d. | 0.15 | 6.03 | n.d. | | | | | | | | | | | | |
| 'Mini Olga' | | | | | | | | | | | | | | 7.60 | 0.03 | n.d. | 0.07 |
| 'Mini Orange' | | | | | | 3.36 | 0.12 | n.d. | 0.07 | | | | | 3.49 | 0.08 | n.d. | 0.09 |
| 'Moonglow' | | 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. |
| 'Mountain Gold' | | 3.60 | 0.03 | n.d. | 0.04 | | | | | | | | | | | | |
| 'Mouse Tomato' | | | | | | | | | | | | | | 3.50 | 0.06 | n.d. | 0.05 |
| 'Old Ivory Egg' | | n.d. | 0.19 | 0.18 | n.d. | | | | | | | | | | | | |
| 'Old Wyandotte' | | 1.47 | 0.02 | n.d. | n.d. | | | | | | | | | | | | |
| 'Olga's Round Golden Chicken Egg' (also known as Olga's Round Yellow Chicken Egg') | | 7.27 | 0.04 | n.d. | n.d. | 2.93 | 0.07 | n.d. | 0.03 | 2.61 | 0.03 | n.d. | 0.06 | 5.13 | 0.03 | n.d. | n.d. |
| 'Orange Beefsteak' | | 4.56 | 0.03 | n.d. | n.d. | | | | | | | | | 3.61 | 0.04 | n.d. | 0.08 |
| 'Orange Bourgoin' | | 3.00 | n.d. | n.d. | 0.02 | | | | | | | | | | | | |
| 'Orange Cherub' | | | | | | 3.44 | 0.07 | 2.95 | 0.11 | | | | | | | | |
| 'Orange Crimea' | | 8.04 | 0.04 | n.d. | 0.03 | 3.86 | 0.03 | n.d. | n.d. | | | | | 9.92 | 0.02 | n.d. | 0.04 |
| 'Orange Fleshed Purple Smudge' | | 6.99 | 0.03 | n.d. | 0.04 | | | | | | | | | 11.40 | 0.03 | n.d. | 0.17 |
| 'Orange Latvian' | | 0.93 | 0.02 | n.d. | n.d. | | | | | | | | | | | | |
| 'Orange Pixie' | | n.d. | 0.22 | 0.14 | 0.03 | | | | | | | | | | | | |
| 'Orange Plum' | | 1.84 | n.d. | n.d. | n.d. | | | | | | | | | | | | |
| 'Orange Queen' | | | | | | 2.41 | n.d. | n.d. | n.d. | | | | | | | | |
| 'Orange Roma' | | 6.92 | 0.02 | n.d. | 0.08 | | | | | | | | | 4.72 | 0.07 | n.d. | 0.09 |
| 'Orange Russian' | | n.d. | 0.14 | 0.98 | 0.90 | | | | | | | | | | | | |
| 'Orange Strawberry' | | 4.14 | 0.03 | n.d. | n.d. | | | | | | | | | 11.86 | 0.04 | n.d. | 0.15 |
| 'Orange Teardrop' | | | | | | 5.31 | 0.14 | n.d. | 0.19 | | | | | 7.01 | 0.04 | n.d. | 0.05 |

| variety | sample | SC13/2015 | | | | TK109/2016 | | | | SC44/2018 | | | | SC54/2019 | | | |
|--|---------|-----------|------|--------|--------|------------|------|--------|--------|-----------|------|--------|--------|-----------|------|--------|--------|
| | | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc |
| 'Orange Valencia' | | 4.60 | 0.06 | n.d. | n.d. | | | | | | | | | | | | |
| 'Pegs Round Orange' | | 0.96 | 0.05 | n.d. | n.d. | | | | | | | | | | | | |
| 'Persimmon' | MB63.20 | 3.82 | 0.04 | n.d. | 0.06 | | | | | | | | | 8.44 | 0.03 | n.d. | 0.13 |
| 'Persimmon' | MB63.34 | 5.24 | n.d. | n.d. | 0.06 | | | | | | | | | | | | |
| 'Primary Colours' | | n.d. | 0.10 | 0.05 | n.d. | | | | | | | | | | | | |
| 'Roughwood Golden Plum' | | 3.82 | 0.13 | n.d. | n.d. | | | | | | | | | | | | |
| 'Russian Persimmon' | MB63.17 | 3.10 | 0.06 | n.d. | n.d. | | | | | | | | | | | | |
| 'Russian Persimmon' | MB63.35 | 2.93 | 0.06 | 0.60 | 0.01 | | | | | | | | | | | | |
| 'Russian Persimmon (red sport)' | MB63.18 | n.d. | 0.26 | 1.25 | 5.98 | | | | | | | | | | | | |
| 'Russian Persimmon (red sport)' | MB63.36 | n.d. | 0.20 | 0.97 | 3.51 | | | | | | | | | | | | |
| 'Sakharniy Zeltiy' | | 3.42 | n.d. | n.d. | n.d. | | | | | | | | | | | | |
| 'Sibirische Orange' | | 4.56 | 0.04 | 0.56 | 0.11 | | | | | | | | | | | | |
| 'Small Lap' | | 2.87 | 0.09 | 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 |
| '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. |
| 'Summer Cider Apricot' | | 6.15 | 0.04 | n.d. | 0.05 | | | | | | | | | | | | |
| 'Tangella' | | 6.13 | 0.03 | n.d. | 0.02 | | | | | 3.67 | 0.04 | n.d. | n.d. | 3.83 | 0.12 | n.d. | 0.28 |
| 'Tangerine' | | | | | | 5.82 | n.d. | n.d. | n.d. | | | | | 4.83 | 0.02 | n.d. | 0.02 |
| 'Tangerine' (fruit covered with paper bag) | | | | | | 4.02 | n.d. | n.d. | n.d. | | | | | | | | |

| variety | sample | SC13/2015 | | | | TK109/2016 | | | | SC44/2018 | | | | SC54/2019 | | | |
|-------------------------------------|---------|-----------|------|--------|--------|------------|-----|--------|--------|-----------|-----|--------|--------|-----------|-----|--------|--------|
| | | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc | TC-Lyc | Lut | b-caro | AT-lyc |
| 'Tess' Landrace Currant (red)' | | n.d. | 0.16 | 1.00 | 4.14 | | | | | | | | | | | | |
| 'Tess' Landrace Currant (yellow)' | | n.d. | 0.29 | 0.34 | n.d. | | | | | | | | | | | | |
| 'Tobolsk' | | 5.73 | 0.04 | n.d. | 0.06 | | | | | | | | | | | | |
| 'Turkey Champ' | | 4.26 | 0.03 | n.d. | 0.02 | | | | | | | | | | | | |
| 'Ueberreich' | | n.d. | 0.03 | 0.03 | n.d. | | | | | | | | | | | | |
| 'Valencia' | | 1.33 | 0.05 | n.d. | n.d. | | | | | | | | | | | | |
| 'West Virginia' | | 5.05 | 0.03 | n.d. | 0.07 | | | | | | | | | | | | |
| 'Wonder (Koanga)' | | n.d. | 0.18 | 0.10 | 0.01 | | | | | | | | | | | | |
| 'Yellow Brandywine Platfoot Strain' | | 4.15 | 0.11 | n.d. | n.d. | | | | | | | | | | | | |
| 'Yellow Oxheart' | | 2.58 | n.d. | n.d. | n.d. | | | | | | | | | | | | |
| 'Yellow Russian' | | 1.48 | 0.02 | n.d. | n.d. | | | | | | | | | | | | |
| 'Yoders Yellow German' | MB63.55 | 2.65 | 0.03 | n.d. | 0.01 | | | | | | | | | | | | |
| 'Yoder's Yellow German' | MB63.72 | 3.40 | 0.03 | n.d. | n.d. | | | | | | | | | | | | |

Confidential report for:
Heritage Food Crops Research Trust

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