



Grapefruit and tomato metabolites for health

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March 2013

A confidential report prepared for

Central Tree Crops Research Trust

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Plant & Food Research, Palmerston North

SPTS No. 8182

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PUBLICATION DATA

McGhie TK. March 2013. Grapefruit and tomato metabolites for health. Central Tree Crops Research Trust. A confidential report prepared for Plant & Food Research: Milestone No. 50743; Contract No. 29092; Job Code No. P/243001/01; SPTS No. 8182.

This report has been prepared by The New Zealand Institute for Plant & Food Research Limited (Plant & Food Research), which has its Head Office at 120 Mt Albert Rd, Mt Albert, Auckland.

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Executive summary

Grapefruit and tomato metabolites for health

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Carotenoid and polyphenol concentrations were measured in the tomato 161 samples provided by the Central Tree Crops Research Trust. Lycopene (*all-trans*-lycopene) was present at the highest concentrations (not detected to 3.62 mg/100 g FW). β -carotene concentrations (not detected to 1.77 mg/100 g FW) and lutein concentrations (0.01 mg/100 g FW to 0.39 mg/100 g FW) were present at lower concentrations. Chlorophyll a was detected in 47 of the samples, with the highest concentration being 0.19 mg/ 100 g FW ('Green Raison').

Tetra-*cis*-lycopene was found in seven of the samples, with the highest concentration being 5.36 mg/100 g FW ('Moonglow'). The presence of high concentrations of tetra-*cis*-lycopene may be of interest as it has recently been reported to be more bioavailable than the usual *all-trans*-lycopene) and therefore the health benefit of these tomatoes may be greater than that of regular tomatoes. Tetra-*cis*-lycopene-containing tomatoes are orange/gold in colour and are readily distinguished from *all-trans*-lycopene containing tomatoes, which are red.

The tomato samples contained a large number of metabolites, and phenolic metabolites were specifically measured using liquid chromatography-high resolution mass spectrometry (LC-HRMS). Caffeic acid esters, such as chlorogenic acid, were present at the highest concentrations. The concentrations of the polyphenolic compounds were highly variable between tomato cultivars.

In grapefruit pith and juice, the polyphenolic compounds present at the greatest concentrations were the flavanones: naringin, narirutin, hesperidin, neohesperidin and eriocitrin. These compounds are typically present in grapefruit and other citrus fruits.

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1 Introduction

A diet rich in fruits and vegetables is well known to reduce the risk of several diseases, such as cardiovascular disease and some cancers. Plant foods, including fruits such as tomato and grapefruit, contain chemical compounds (metabolites or phytochemicals), and it is these metabolites that are considered to be beneficial for the health of human consumers. The metabolite composition within each plant type varies by cultivar, climate and production system. There is also a view that modern fruit cultivars contain lower concentrations of health-promoting metabolites than older 'heritage' cultivars.

The aim of this project was to identify and measure metabolites in heritage cultivars of tomato and grapefruit that are considered to be beneficial to health. Metabolites were extracted from fruit samples with organic solvent and prepared for analysis by liquid chromatography-high resolution mass spectrometry (LC-HRMS).

2 Materials and methods

2.1 Sampling

Samples of tomato and grapefruit samples were collected by Mark Christensen, Central Tree Crops Research Trust, and sent by courier to Plant & Food Research, Palmerston North. All samples were frozen (-18°C) on arrival and stored frozen until analysis.

Tomato samples were homogenised using a Hobart food chopper, while being kept frozen using dry ice.

Frozen grapefruit were mounted on a skin peeler and the outer coloured layer removed. The underlying white pith layer was then removed for metabolite analysis. The fruit were allowed to thaw and then juiced in a domestic electric fruit juicer.

2.2 Tomato: carotenoid analysis

Portions of the homogenised samples were extracted with tetrahydrofuran:methanol, with the addition of anhydrous Na₂SO₄ and Na₂CO₃ and the carotenoid composition was measured by High Performance Liquid Chromatography (HPLC).

Authentic carotenoid standards (lutein, β-carotene, and lycopene) were used to identify and quantify each compound by retention time and spectral properties. Tetra-*cis*-lycopene was identified by reference to previously published research on tomatoes and was quantified as all-*trans*-lycopene equivalents.

2.3 Tomato: polyphenol analysis

Portions of the homogenised samples were extracted with ethanol/water/formic acid and the metabolite composition was measured by LC-HRMS.

Authentic polyphenol standards were used to identify and quantify compounds where possible. When a standard was not available, the component was identified by reference to previously published research on tomatoes and was quantified using a chemically similar compound.

2.4 Grapefruit: polyphenol analysis

Portions of the pith were extracted with ethanol/water/formic acid and the metabolite composition was measured by LC-HRMS. The juice was diluted with methanol and the metabolite composition was measured by LC-HRMS. All compounds were quantified as naringin equivalents.

3 Results and discussion

3.1 Tomatoes

Table 1 shows the concentrations of carotenoids present in the 161 samples provided. Lycopene (all-*trans*-lycopene) was present at the highest concentrations and these ranged from not detected (e.g. in 'Andean Tomato') to 3.62 mg/100 g FW ('Rosalita'). Tetra-*cis*-lycopene was found in seven of the samples, with the highest concentration being 5.36 mg/100 g FW ('Moonglow'). β -carotene concentrations ranged from not detected (e.g. in 'Pik's White') to 1.77 mg/100 g FW ('Surrey's Orange Delight'). Lutein concentrations ranged from 0.01 mg/100 g FW ('Black Master') to 0.39 mg/100 g FW ('Galapagos Island'). Chlorophyll a was found in 47 of the samples, with the highest concentration being 0.19 mg/ 100 g FW ('Green Raison'). The presence of high concentrations of tetra-*cis*-lycopene may be of interest, as it has recently been reported to be more bioavailable than the usual all-*trans*-lycopene (Ishida et al. 2007; Burri et al. 2009) (see Appendix) and therefore the health benefit of these tomatoes may be greater than regular tomatoes. Furthermore, tetra-*cis*-lycopene-containing tomatoes are orange/gold in colour and are readily distinguished from all-*trans*-lycopene containing tomatoes, which are red.

Overall, the carotenoid concentrations show large variations and the concentration ranges are similar to those reported previously by PFR.

Table 1: Concentrations of carotenoids in tomato cultivars provided by the Central Tree Crops Research Trust.

Tomato Cultivar	Carotenoids (mg/100 g FW)				Total	Chlorophyll a
	Lutein	β -carotene	lycopene	C ⁴ -lycopene		
'Allegheny Sunset'	0.08	0.28	0.40	n.d.	0.77	n.d.
'Amish Oxheart'	0.05	n.d.	0.02	2.67	2.75	n.d.
'Amish Sherbert Heirloom'	0.02	n.d.	0.01	4.35	4.38	n.d.
'Big Yellow Zebra'	0.04	0.19	0.40	n.d.	0.63	n.d.
'Arbuznyi'	0.06	0.23	0.39	n.d.	0.79	0.11
'Arkansas Marvel'	0.09	0.21	0.04	n.d.	0.34	n.d.
'Armenian'	0.12	0.30	0.15	n.d.	0.57	n.d.
'Aunt Gertie's Gold'	0.04	n.d.	0.02	4.21	4.27	n.d.
'Basinga'	0.10	0.08	0.12	n.d.	0.31	n.d.
'Beauty Queen'	0.14	0.33	0.18	n.d.	0.65	n.d.
'Bianca'	0.17	0.11	n.d.	n.d.	0.27	n.d.
'Big Orange'	0.02	1.36	0.03	3.79	5.21	n.d.
'Andean Tomato'	0.10	0.05	n.d.	n.d.	0.15	n.d.
'Black Alsberg'	0.12	0.30	0.05	n.d.	0.55	0.08
'Black Altai'	0.14	0.25	0.08	n.d.	0.47	n.d.
'Black Early'	0.14	0.30	0.07	n.d.	0.60	0.10
'Black Ethiopian'	0.05	0.45	0.83	n.d.	1.48	0.15
'Black Marizol'	0.09	0.19	0.42	n.d.	0.79	0.09
'Black Master'	0.01	0.30	0.42	n.d.	0.73	n.d.
'Black Mystery'	0.02	0.27	0.75	n.d.	1.15	0.11
'Black Pearl'	0.21	0.49	0.95	n.d.	1.81	0.16
'Black Star'	0.13	0.25	0.52	n.d.	0.89	n.d.
'Brad's Black Heart'	0.04	0.25	0.50	n.d.	0.78	n.d.
'Brazilian Beauty'	0.07	0.39	0.78	n.d.	1.39	0.16
'Chalalis'	0.10	0.24	0.45	n.d.	0.80	n.d.
'Cherokee Green'	0.14	0.08	0.01	n.d.	0.34	0.12
'Coyote'	0.20	0.06	n.d.	n.d.	0.26	n.d.
'Cuatomate'	0.23	1.11	0.76	n.d.	2.22	0.12
'Daniella' (modern hybrid)	0.09	0.28	0.40	n.d.	0.78	n.d.
'Eclipse'	0.26	0.39	0.66	n.d.	1.46	0.16
'Edith's Giant Tomato'	0.11	0.25	0.42	n.d.	0.77	n.d.
'Elley'	0.05	0.35	0.51	n.d.	1.01	0.09
'Eric'	0.11	0.34	0.55	n.d.	0.99	n.d.
'Evan,s Purple Pear'	0.29	0.43	0.60	n.d.	1.49	0.17
'Fruit Punch Cherry'	0.14	0.74	0.64	n.d.	1.59	0.07
'Furry Red Boar'	0.13	0.25	0.54	n.d.	0.92	n.d.
'Gajo De Melon' (Red)	0.13	0.56	0.69	n.d.	1.39	n.d.
'Gajo De Melon' (Yellow)	0.10	0.06	n.d.	n.d.	0.16	n.d.
'Galapagos Island'	0.39	0.46	0.63	n.d.	1.59	0.11
'Galinas'	0.10	0.10	n.d.	n.d.	0.19	n.d.
'German Gold'	0.09	0.30	0.33	n.d.	0.72	n.d.
'Giallo a Grappoli'	0.07	0.65	0.31	n.d.	1.16	0.12
'Giant Fiolet'	0.18	0.47	0.61	n.d.	1.40	0.14
'Glick's Brandywine'	0.10	0.30	0.54	n.d.	0.95	n.d.
'Golden Gem'	0.20	0.23	0.01	n.d.	0.44	n.d.
'Grandma Oliver's Green'	0.03	0.08	0.01	n.d.	0.22	0.09
'Grandma's Low Acid'	0.12	0.25	0.51	n.d.	0.96	0.08
'Grandpa's Low Acid Variety'	0.09	0.28	0.34	n.d.	0.79	0.07
'Green Bell Pepper'	0.09	0.11	0.01	n.d.	0.30	0.09
'Green Moldovan'	0.19	0.23	0.04	n.d.	0.63	0.17
'Green Pineapple'	0.07	0.07	0.04	n.d.	0.17	n.d.
'Green Raisan'	0.22	0.12	n.d.	n.d.	0.53	0.19
'Gregori's Altai'	0.10	0.34	2.61	n.d.	3.05	n.d.
'Grubb's Mystery Green'	0.12	0.11	0.04	n.d.	0.38	0.12
'Grubb's Mystery Green-Orange'	0.10	0.21	0.86	n.d.	1.17	n.d.
'Grushovka'	0.12	0.36	2.81	n.d.	3.30	n.d.
'Gypsy Tsygan Black'	0.21	0.29	2.75	n.d.	3.40	0.15
'Hahnstown Yellow'	0.10	0.07	0.09	n.d.	0.26	n.d.

Tomato Cultivar	Carotenoids (mg/100 g FW)				Total	Chlorophyll a
	Lutein	β -carotene	lycopene	C ⁴ -lycopene		
'Hartman's Yellow Gooseberry'	0.13	0.09	n.d.	n.d.	0.23	n.d.
'Indian'	0.20	0.36	1.92	n.d.	2.63	0.15
'Italian Sweet'	0.10	0.23	2.66	n.d.	2.98	n.d.
'Izumrudnoe Yabloko'	0.10	0.17	0.01	n.d.	0.40	0.12
'Jen's Giant'	0.10	0.26	2.17	n.d.	2.53	n.d.
'Kalman Hongroise'	0.11	0.34	2.22	n.d.	2.66	n.d.
'Kibit's Ukrainian'	0.22	0.45	2.32	n.d.	3.13	0.14
'Kiev'	0.27	0.41	2.77	n.d.	3.55	0.10
'King Humbert' ('Roi Humbert')	0.22	0.52	2.09	n.d.	2.95	0.12
'Kiwi'	0.08	0.22	0.02	n.d.	0.49	0.18
'Lancaster County Pink'	0.17	0.28	1.26	n.d.	1.71	n.d.
'Limmony'	0.13	0.29	0.75	n.d.	1.17	n.d.
'Mammoth German Gold'	0.09	0.27	0.25	n.d.	0.61	n.d.
'Manyel'	0.09	0.10	n.d.	n.d.	0.20	n.d.
'Marizol Gold'	0.07	0.35	0.08	n.d.	0.49	n.d.
'Marizol Gold' (large)	0.11	0.19	0.05	n.d.	0.35	n.d.
'Marizol Gold Cherry'	0.17	0.43	0.13	n.d.	0.72	n.d.
'Marizol Majic'	0.25	0.51	0.31	n.d.	1.07	n.d.
'Marvel Stripe'	0.12	0.26	0.20	n.d.	0.58	n.d.
'Maryland Large Red'	0.15	0.27	0.32	n.d.	0.73	n.d.
'Matina'	0.17	0.45	0.05	n.d.	0.67	n.d.
'Mennonite'	0.08	0.32	0.15	n.d.	0.64	0.09
'Mexico'	0.16	0.29	0.03	n.d.	0.48	n.d.
'Midnight in Moscow'	0.15	0.22	0.04	n.d.	0.41	n.d.
'Millefleur'	0.24	0.11	n.d.	n.d.	0.36	n.d.
'Moonglow'	0.06	n.d.	0.05	5.36	5.48	n.d.
'Nectarine'	0.17	0.71	0.14	n.d.	1.01	n.d.
'Nineveh'	0.15	0.30	0.13	n.d.	0.58	n.d.
'Noire Charbonneuse'	0.13	0.17	0.11	n.d.	0.49	0.08
'Noire de Cosseboeuf'	0.18	0.23	0.14	n.d.	0.67	0.12
'Noire Russe Charbonniere'	0.24	0.32	0.09	n.d.	0.74	0.10
'Oliguosa'	0.14	0.40	0.08	n.d.	0.62	n.d.
'Orange Fleshed Purple Smudge'	0.09	n.d.	0.06	4.36	4.50	n.d.
'Oxheart'	0.10	0.27	0.09	n.d.	0.46	n.d.
'Peach Blow Sutton'	0.13	0.37	0.08	n.d.	0.59	n.d.
'Peru'	0.19	0.37	0.02	n.d.	0.58	n.d.
'Piedmont'	0.19	0.22	0.04	n.d.	0.57	0.13
'Pik's White'	0.07	n.d.	n.d.	n.d.	0.07	n.d.
'Pik's Yugo'	0.13	0.23	n.d.	n.d.	0.35	n.d.
'Pineapple Golden'	0.08	0.32	0.01	n.d.	0.41	n.d.
'Pink Ping Pong'	0.15	0.38	0.06	n.d.	0.59	n.d.
'Pimento Roma'	0.15	0.19	0.05	n.d.	0.39	n.d.
'Polish'	0.09	0.22	0.06	n.d.	0.37	n.d.
'Polish Pastel'	0.15	0.22	0.62	n.d.	0.99	n.d.
'Power's'	0.12	0.15	n.d.	n.d.	0.27	n.d.
'Power's Heirloom Paste'	0.08	0.10	n.d.	n.d.	0.18	n.d.
'Purple Perfect'	0.06	0.21	2.07	n.d.	2.34	n.d.
'Purple Prince'	0.11	0.33	2.64	n.d.	3.21	0.13
'Purple Smudge'	0.18	0.42	2.53	n.d.	3.13	n.d.
'Red Streak'	0.10	0.34	0.43	n.d.	0.88	n.d.
'Rosabec'	0.11	0.27	2.87	n.d.	3.25	n.d.
'Rosalita'	0.22	0.61	3.62	n.d.	4.45	n.d.
'Royal Red'	0.16	0.20	1.26	n.d.	1.72	0.10
'Russian Chocolate'	0.19	0.31	2.16	n.d.	2.83	0.17
'Russian Pear'	0.23	0.31	2.12	n.d.	2.76	0.10
'Sarah Schwarze'	0.20	0.20	2.70	n.d.	3.10	n.d.
'Scabitha'	0.16	0.59	2.49	n.d.	3.24	n.d.
'Schimmeig Striped'	0.19	0.38	2.03	n.d.	2.61	n.d.
'Seattle Best-of-All'	0.16	0.40	1.91	n.d.	2.46	n.d.
'Shugan'	0.25	0.33	1.98	n.d.	2.73	0.16

Tomato Cultivar	Carotenoids (mg/100 g FW)				Total	Chlorophyll a
	Lutein	β -carotene	lycopene	C ⁴ -lycopene		
'Sibirische Orange'	0.04	n.d.	0.03	1.72	1.80	n.d.
'Soldacki'	0.15	0.29	1.44	n.d.	1.88	n.d.
'Spear's Tennessee'	0.17	0.07	n.d.	n.d.	0.36	0.13
'Striped German'	0.18	0.38	0.29	n.d.	0.85	n.d.
'Striped Turkish'	0.16	0.79	0.74	n.d.	1.70	n.d.
'Surrey's Orange Delight'	0.09	1.47	0.44	n.d.	2.00	n.d.
'Sweet Williams'	0.17	0.58	0.40	n.d.	1.15	n.d.
'Tangerine'	0.05	n.d.	n.d.	4.43	4.48	n.d.
'Taxi'	0.09	0.09	n.d.	n.d.	0.17	n.d.
'Tennessee S'rprise'	0.08	0.29	0.20	n.d.	0.57	n.d.
'Tlacolula Pink' – Mexico	0.10	0.29	0.22	n.d.	0.62	n.d.
'Togorific'	0.13	0.35	0.17	n.d.	0.66	n.d.
'Transparent'	0.10	0.05	n.d.	n.d.	0.15	n.d.
'Transparent Heirloom Yellow'	0.10	0.05	n.d.	n.d.	0.15	n.d.
'Violet Jaspers'	0.25	0.52	0.15	n.d.	1.05	0.14
'Walthrup Green'	0.13	0.06	n.d.	n.d.	0.20	n.d.
'Whippersnapper'	0.26	0.42	0.12	n.d.	0.80	n.d.
'White Zea Sonnabend'	0.08	n.d.	n.d.	n.d.	0.08	n.d.
'White Zebra'	0.07	n.d.	n.d.	n.d.	0.07	n.d.
'Winterkeeper'	0.09	0.71	0.09	n.d.	1.01	0.12
'Wuhib'	0.17	0.25	0.08	n.d.	0.50	n.d.
'Yellow Out Red In'	0.10	0.29	0.04	n.d.	0.43	n.d.
'Yellow Ping Pong'	0.14	0.10	n.d.	n.d.	0.24	n.d.
'Yellow Red Low Acid'	0.14	0.27	0.04	n.d.	0.44	n.d.
'Yellow Striped Boar'	0.13	0.26	0.04	n.d.	0.43	n.d.
'Yellow Tomato'	0.15	0.11	n.d.	n.d.	0.26	n.d.
'Zigan Gypsy'	0.25	0.30	n.d.	n.d.	0.55	n.d.
'Zogolla'	0.13	0.29	n.d.	n.d.	0.42	n.d.
'Afghanistan'	0.21	0.30	n.d.	n.d.	0.52	n.d.
'Big Zebra'	0.17	0.35	n.d.	n.d.	0.62	0.10
'Black Crimson'	0.13	0.28	n.d.	n.d.	0.49	0.07
'Bordo'	0.16	0.22	n.d.	n.d.	0.47	0.10
'Burracker's Favourite'	0.17	0.29	n.d.	n.d.	0.45	n.d.
'Cuban Black'	0.23	0.18	n.d.	n.d.	0.52	0.11
'De Baro Gold'	0.12	0.10	n.d.	n.d.	0.22	n.d.
'Earl of Edgecombe'	0.07	n.d.	n.d.	2.63	2.70	n.d.
'Elbe'	0.06	n.d.	n.d.	2.45	2.51	n.d.
'Feurwerk'	0.14	0.24	n.d.	n.d.	0.37	n.d.
'Green Gage' (Orange)	0.21	0.11	n.d.	n.d.	0.32	n.d.
'Belarus Crimson'	0.16	0.11	n.d.	n.d.	0.27	n.d.
'Bear Claw'	0.09	0.32	1.23	n.d.	1.64	n.d.
'Madara'	0.15	0.07	0.01	n.d.	0.23	n.d.
'Natasha's Choice'	0.30	0.68	1.22	n.d.	2.19	n.d.

n.d. = not detected
lycopene = all-trans-lycopene
C⁴-lycopene = tetra-cis-lycopene

Tomatoes contain a large number of metabolites and many of these have been tentatively identified (Gomez-Romero et al. 2010). In these analyses, we have specifically measured phenolic metabolites using LC-HRMS. Caffeic acid esters, such as chlorogenic acid, were present at the highest concentrations. The concentrations of the polyphenolic compounds were highly variable among tomato cultivars.

Table 2: Concentrations of polyphenols in tomato cultivars provided by the Central Tree Crops Research Trust.

Sample	Polyphenol Conc. (mg/100 g FW)							
	CouQA	CafA	CafHex	CQA	DCQA	Q-rut	Q-rutpent	Nar
'Allegheny Sunset'	0.04	0.34	1.19	2.14	0.58	0.59	0.18	0.09
'Amish Yellowish Orange Oxheart'	0.16	0.51	0.92	5.58	1.28	1.40	0.41	0.46
'Amisn Orange Sherbert Heirloom'	0.29	0.58	1.21	1.55	0.15	0.11	0.13	n.d.
'Big Yellow Zebra'	0.03	0.39	1.67	1.48	0.41	0.90	0.29	2.74
'Arbuznyi'	0.06	0.44	0.77	2.34	0.59	1.65	0.38	3.50
'Arkansas Marvel'	0.02	0.46	0.88	0.44	0.05	0.30	0.14	0.01
'Armenian'	0.08	0.74	1.01	2.59	0.58	0.63	0.24	0.03
'Aunt Gertie's Gold'	0.03	0.56	1.13	2.45	0.81	0.67	0.16	1.98
'Basinga'	0.19	0.47	1.40	2.82	0.82	0.92	0.20	n.d.
'Beauty Queen'	0.24	0.65	1.34	2.33	0.67	0.62	0.20	0.14
'Bianca'	0.76	0.65	1.25	n.d.	7.61	2.36	0.64	7.66
'Big Orange'	0.18	0.48	1.74	2.28	1.01	1.22	0.26	0.07
'Andean Tomato'	0.34	0.83	1.49	5.06	1.21	0.90	0.26	2.72
'Black Alsberg'	0.17	0.34	0.88	4.52	1.33	2.14	0.49	3.96
'Black Altai'	0.13	0.28	1.02	3.15	1.41	2.71	0.54	3.65
'Black Early'	0.19	0.57	1.25	2.35	0.70	0.93	0.28	0.99
'Black Ethiopian'	0.37	0.28	1.21	3.16	1.79	1.71	0.87	5.99
'Black Marizol'	0.13	0.33	0.95	2.25	0.70	0.65	0.19	0.33
'Black Master'	0.09	0.31	1.11	2.66	1.21	3.27	0.59	0.95
'Black Mystery'	0.17	0.47	0.90	4.79	1.59	3.38	0.63	1.06
'Black Pearl'	1.05	0.52	1.49	5.20	2.50	2.28	0.64	5.92
'Black Star'	0.35	0.26	0.79	3.37	0.81	0.61	0.15	0.04
'Brad's Black Heart'	0.09	0.26	1.00	2.45	1.25	1.92	0.46	0.59
'Brazilian Beauty'	0.20	0.43	1.02	3.01	1.03	1.58	0.39	6.31
'Chalalis'	0.09	0.21	0.81	2.10	0.78	0.63	0.15	0.06
'Cherokee Green'	0.46	0.60	0.85	2.98	0.85	0.66	0.12	4.32
'Coyote'	0.50	0.91	1.75	7.95	11.10	2.65	0.65	0.61
'Cuatomate'	1.23	1.38	1.12	16.16	14.01	3.70	0.60	2.78
'Daniella' (modern hybrid)	0.04	0.55	0.70	1.03	0.21	1.08	0.65	2.41
'Eclipse'	0.40	0.31	0.91	6.38	1.95	3.00	0.69	5.03
'Edith's Giant Tomato'	0.14	0.18	0.80	3.15	1.98	1.72	0.33	6.60
'Elley'	0.13	0.26	1.28	2.08	0.71	0.74	0.23	0.02
'Eric'	0.28	0.52	1.53	3.39	1.50	1.72	0.31	2.44
'Evan's Purple Pear'	0.40	0.43	0.91	4.58	1.11	1.17	0.49	0.09
'Fruit Punch Cherry'	1.31	0.24	1.44	5.90	3.43	1.51	0.62	0.01
'Furry Red Boar'	1.00	0.64	0.82	4.62	1.28	0.48	0.30	3.88
'Gajo De Melon (Red)'	0.82	0.39	0.63	6.18	1.48	0.85	0.33	2.31
'Gajo De Melon (Yellow)'	1.28	0.30	0.23	9.50	0.00	0.53	0.39	0.14
'Galapogas Island'	0.15	0.75	1.08	6.88	9.85	2.21	0.65	8.17
'Galinas'	0.35	1.06	2.27	3.37	0.74	1.29	0.42	2.25
'German Gold'	0.12	0.72	1.46	2.17	1.45	0.55	0.16	0.02
'Giallo a Grappoli'	0.05	0.29	0.38	6.38	0.00	0.47	0.36	1.49
'Giant Fiolet'	0.45	0.66	0.83	3.16	0.73	0.68	0.36	0.05
'Glick's Brandywine'	0.21	0.38	0.81	3.79	1.23	1.06	0.21	0.20
'Golden Gem'	0.87	0.67	0.70	10.95	11.14	5.93	0.69	8.65
'Grandma Oliver's Green'	0.65	0.65	0.74	3.78	0.56	0.81	0.28	1.17
'Grandma's Low Acid'	0.11	0.48	0.97	2.15	0.59	0.40	0.13	n.d.
'Grandpa's Low Acid Variety'	0.02	0.46	0.59	0.60	0.09	0.19	0.08	0.01
'Green Bell Pepper'	0.51	0.35	0.82	3.13	1.36	0.76	0.27	3.48
'Green Moldovan'	0.34	0.44	0.97	2.63	0.49	1.80	0.41	0.82
'Green Pineapple'	0.44	0.53	0.70	4.66	0.75	1.40	0.42	1.26
'Green Raisan'	0.80	0.59	1.27	4.64	1.47	1.89	0.22	6.33
'Gregori's Altai'	0.35	0.41	1.04	2.98	1.38	0.67	0.14	0.05
'Grubb's Mystery Green'	0.26	0.84	1.38	1.10	0.24	1.67	0.29	0.58
'Grubb's Mystery Green-Orange'	0.15	0.49	1.34	1.81	0.61	1.05	0.29	1.27
'Grushovka'	0.48	0.51	0.85	2.42	0.60	0.69	0.28	0.06
'Gypsy Tsygan Black'	0.53	0.45	1.44	3.29	0.82	1.52	0.92	0.23
'Hahnstown Yellow'	0.18	0.57	1.55	2.25	0.45	1.36	0.28	2.78
'Hartman's Yellow Gooseberry'	0.40	1.19	1.92	4.01	1.73	1.24	0.77	0.49

Sample	Polyphenol Conc. (mg/100 g FW)							
	CouQA	CafA	CafHex	CQA	DCQA	Q-rut	Q-rutpent	Nar
'Indian'	0.20	0.46	0.85	3.27	0.93	1.42	0.61	0.28
'Italian Sweet'	0.24	0.56	1.10	3.06	1.09	1.16	0.42	0.13
'Izumrudnoe Yabloko'	0.26	0.40	0.84	3.69	1.28	2.41	0.43	4.84
'Jen's Giant'	0.14	0.28	0.79	2.34	0.57	0.72	0.20	0.06
'Kalman Hongroise'	0.11	0.33	1.45	2.25	0.50	0.64	0.29	0.07
'Kibit's Ukrainian'	0.32	0.59	1.86	4.55	1.94	2.34	0.59	3.36
'Kiev'	0.24	0.37	1.40	3.00	0.82	2.06	0.59	0.74
'Kiwi'	0.41	0.42	0.90	4.23	1.38	2.59	0.50	4.56
'Lancaster County Pink'	0.53	0.48	1.20	4.02	0.99	1.57	0.26	1.94
'Limmony'	0.14	0.53	1.37	2.31	0.65	0.79	0.26	0.08
'Mammoth German Gold'	0.02	0.41	1.01	0.75	0.36	0.12	0.10	n.d.
'Manyel'	0.24	0.26	0.92	2.52	0.63	0.99	0.24	2.33
'Marizol Gold'	0.02	0.39	1.20	0.38	0.04	0.22	0.13	n.d.
'King Humbert (Roi Humbert)'	0.23	0.51	1.19	2.74	0.59	1.29	0.53	1.01
'Marizol Gold' (large)	0.04	0.42	0.81	0.64	0.17	0.10	0.09	n.d.
'Marizol Gold Cherry'	0.25	0.82	1.31	2.82	1.16	0.73	0.31	0.20
'Marizol Majic'	1.02	0.63	1.61	2.52	0.49	1.09	0.34	0.12
'Marvel Stripe'	0.04	0.47	0.76	0.49	0.10	0.06	0.06	n.d.
'Maryland Large Red'	0.32	0.39	1.14	2.78	0.94	1.17	0.24	0.82
'Matina'	0.39	0.63	0.92	2.96	0.92	1.56	0.40	4.15
'Mennonite'	0.02	0.14	1.37	1.37	0.30	0.49	0.07	0.04
'Mexico'	0.43	0.49	0.71	3.34	0.97	0.85	0.23	0.89
'Midnight in Moscow'	0.22	0.44	0.83	3.18	1.15	0.50	0.21	0.07
'Millefleur'	0.29	1.02	1.15	4.66	2.89	1.55	0.32	1.57
'Moonglow'	0.15	0.60	1.28	2.12	0.50	1.14	0.28	1.17
'Nectarine'	0.40	0.82	1.57	2.41	0.38	0.67	0.25	0.14
'Nineveh'	0.56	0.50	0.99	4.29	1.64	1.91	0.32	4.01
'Noire Charbonneuse'	0.39	0.52	0.87	3.07	0.85	0.55	0.23	0.10
'Noire de Cosseboeuf'	0.22	0.46	0.93	4.76	2.53	0.92	0.29	0.08
'Noire Russe Charbonniere'	0.14	0.39	1.19	2.32	1.19	2.78	0.54	5.62
'Oliguosa'	0.03	0.60	1.58	3.99	1.88	0.93	0.24	0.02
'Orange Fleshed Purple Smudge'	0.14	0.53	0.83	2.03	0.43	0.53	0.16	n.d.
'Oxheart'	0.22	0.45	1.22	2.62	1.12	1.49	0.44	1.95
'Peach Blow Sutton'	1.04	0.60	1.30	5.17	1.06	0.66	0.14	0.50
'Peru'	0.19	0.73	1.58	6.67	2.82	0.46	0.22	0.16
'Piedmont'	0.08	0.50	1.47	2.85	0.75	0.45	0.35	0.03
'Pik's White'	0.08	0.40	0.96	3.13	0.99	1.25	0.22	0.08
'Pik's Yugo'	0.21	0.35	1.09	2.72	0.58	0.60	0.14	0.07
'Pineapple Golden'	0.03	0.29	1.22	1.70	0.41	0.61	0.13	0.09
'Pink Ping Pong'	0.25	0.74	1.87	3.21	0.87	0.13	0.21	n.d.
'Pimento Roma'	0.02	0.30	0.99	2.89	1.02	1.69	0.43	6.15
'Polish Pastel'	0.02	0.19	0.91	1.55	0.46	0.73	0.24	0.06
'Power's'	0.21	0.71	1.82	2.21	0.53	1.14	0.41	0.11
'Power's Heirloom Paste'	0.14	0.41	1.12	2.88	1.21	1.08	0.32	0.08
'Purple Perfect'	0.23	0.42	0.75	2.12	0.65	0.98	0.35	0.23
'Purple Prince'	0.14	0.49	1.18	2.25	0.71	3.17	0.72	0.49
'Purple Smudge'	0.38	0.27	0.87	3.60	0.91	1.14	0.39	0.14
'Red Streak'	0.09	0.32	1.25	1.97	0.62	0.78	0.19	0.14
'Rosabec'	0.12	0.35	0.99	1.94	0.64	0.58	0.21	0.02
'Rosalita'	0.62	0.65	1.29	6.08	2.79	0.94	0.61	0.14
'Royal Red'	0.20	0.32	0.62	3.05	1.13	0.90	0.27	5.02
'Russian Chocolate'	0.89	0.38	1.04	3.46	0.98	1.50	0.47	0.28
'Russian Pear'	0.44	0.36	1.10	3.19	0.58	1.08	0.26	5.70
'Sarah Schwarze'	0.42	0.42	1.33	4.46	1.11	0.89	0.18	0.20
'Scabitha'	0.22	0.58	1.11	4.56	2.08	1.62	0.49	5.22
'Schimmeig Striped''	0.52	0.33	0.89	3.66	1.02	0.95	0.27	3.16
'Seattle Best-of-All'	0.51	0.40	0.63	3.09	0.89	1.56	0.59	6.43
'Shugan'	0.52	0.36	1.16	3.19	0.82	1.32	0.46	0.27
'Sibirische Orange'	0.24	0.33	0.69	2.85	1.39	1.14	0.32	0.20
'Soldacki'	0.11	0.29	0.69	2.14	0.77	0.69	0.23	0.27

Sample	Polyphenol Conc. (mg/100 g FW)							
	CouQA	CafA	CafHex	CQA	DCQA	Q-rut	Q-rutpent	Nar
'Spear's Tennessee'	0.71	0.51	0.47	6.48	0.66	0.95	0.25	3.67
'Striped German'	0.18	0.70	1.63	2.83	0.94	0.69	0.17	0.15
'Striped Turkish'	0.21	1.28	1.57	3.56	0.81	0.48	0.21	0.79
'Surrey's Orange Delight'	0.45	0.30	0.61	4.24	1.43	1.07	0.35	7.16
'Sweet Williams'	0.38	0.71	1.98	6.17	1.61	1.36	0.39	1.16
'Tangerine'	0.16	0.45	1.04	2.50	1.24	1.29	0.36	5.89
'Taxi'	0.20	0.50	1.07	4.08	1.47	2.26	0.39	6.26
'Tennessee Suprise'	0.31	0.34	0.81	3.31	1.12	0.82	0.17	3.19
'Tlacolula Pink – Mexico'	0.37	0.37	0.79	4.28	1.28	0.91	0.32	0.90
'Togorific'	0.33	0.56	1.14	6.20	3.50	0.96	0.41	0.34
'Transparent'	0.31	0.75	1.15	4.10	1.79	1.19	0.72	0.33
'Transparent Heirloom Yellow'	0.57	0.68	1.26	3.46	0.89	0.64	0.30	0.05
'Violet Jaspers'	0.12	1.14	1.25	1.61	0.52	0.16	0.18	0.01
'Walthrup Green'	0.15	0.71	1.38	1.05	0.26	0.60	0.22	1.68
'Whippersnapper'	0.29	0.51	0.79	6.58	1.96	1.07	0.63	1.32
'White Zea Sonnabend'	0.55	0.58	0.95	2.37	0.71	1.00	0.27	0.03
'White Zebra'	0.37	0.57	0.90	5.10	2.42	0.91	0.65	0.33
'Winterkeeper'	0.08	0.76	1.03	3.04	0.66	0.68	0.35	0.95
'Wuhib'	0.27	0.13	0.55	2.97	1.21	0.54	0.27	7.39
'Yellow Out Red In'	0.15	0.45	0.59	3.80	1.04	1.04	0.28	1.92
'Yellow Ping Pong'	0.37	0.38	0.69	6.67	4.02	1.48	0.47	7.80
'Yellow Red Low Acid'	0.08	0.44	0.93	1.57	0.57	0.48	0.11	0.20
'Yellow Striped Boar'	0.06	1.01	1.45	1.64	0.50	0.54	0.20	0.05
'Yellow Tomato'	0.29	0.59	1.13	3.71	1.56	0.90	0.36	2.88
'Zigan Gypsy'	0.53	0.44	0.94	2.93	0.74	1.31	0.53	0.17
'Zogolla'	0.28	0.43	0.85	3.49	1.52	0.81	0.29	0.27
'Afghanistan'	0.42	0.61	1.08	3.15	1.00	0.94	0.29	0.19
'Big Zebra'	0.39	0.85	0.91	2.27	0.65	0.90	0.17	2.65
'Black Crimson'	0.36	0.78	1.08	2.29	0.56	0.79	0.23	0.11
'Bordo'	0.62	0.64	1.04	3.09	0.80	1.24	0.27	1.15
'Burracker's Favourite'	0.15	0.50	1.19	2.67	1.23	0.93	0.24	0.07
'Cuban Black'	0.28	0.56	1.34	2.69	0.73	1.13	0.49	1.41
'De Baro Gols'	0.54	0.33	1.27	3.74	0.82	1.09	0.65	1.25
'Earl of Edgcombe'	0.29	0.49	0.83	2.44	0.60	0.40	0.24	2.95
'Elbe'	0.31	0.54	0.91	6.20	1.67	1.04	0.23	3.31
'Feurwerk'	0.59	0.60	1.31	4.67	1.56	1.37	0.21	4.36
'Green Gage' (Orange)	0.19	1.03	1.52	3.01	0.87	0.87	0.38	0.62
'Belarus Crimson'	0.06	0.56	0.76	3.19	1.13	0.94	0.34	3.30
'Polish'	0.29	0.47	0.99	2.76	1.13	0.73	0.16	0.18
'Bear Claw'	0.18	0.83	1.59	1.19	0.21	0.42	0.20	n.d.
'Madara'	0.61	0.87	2.07	2.84	1.42	0.78	0.18	4.57
'Natasha's Choice'	0.38	0.97	1.02	1.67	0.40	1.06	0.38	1.48

CouQA = *p*-coumaryl quinic acid

CafA = caffeic acid

CafHex = caffeoyl hexoside

CQA = chlorogenic acid (caffeoyl quinic acid)

DCQA = dicaffeoyl quinic acid

Q=rut = quercetin 3-rutinoside

Q-rutpent = quercetin 3-rutinylpentoside

Nar = naringenin (or naringenin chalcone)

3.2 Grapefruit

The concentrations of the polyphenolic metabolites measured in the pith and juice of the 11 grapefruit samples provided are shown below in Table 3. The polyphenolic compounds present in both the pith and the juices at the greatest concentrations were the flavanones: naringin, narirutin, hesperidin, neohesperidin and eriocitrin. These compounds are typically present in grapefruit and other citrus fruits (Rouseff et al. 1987; Abad-Garcia et al. 2012).

Table 3: Concentrations of polyphenols in grapefruit selection cultivars provided by the Central Tree Crops Research Trust.

Name	Nar	Nar-rut	Nar-glu	Hes	neoHe	Eri	Pon
Pith							
Polyphenol Concentrations (ug/g FW)							
J. Fergusson, Drury	6679	2390	612	6602	2669	1487	235
'Golden Special'	8458	1684	1022	6364	1522	2270	400
J. Stewart, Manukau	7682	1336	938	6996	1580	1570	443
Josette Howell	8099	2317	958	6326	1924	1372	393
S. Kellam & P. Merten	7938	1707	1007	6910	1825	1672	389
J.&W. Knoche, Wanganui	7089	1674	967	6110	1532	1222	254
'Poorman's Orange'	7170	1216	713	6153	1455	1324	305
L. Sorenson, Waitotara	6640	1330	749	5594	1295	1153	180
Toi Street, Wanganui	7851	2948	699	7120	3258	1897	261
J. Trower, Matamata'	7618	1429	677	6161	1539	1336	339
'Wheeny'	8146	3209	536	6671	2935	1772	240
Juice							
Polyphenol Concentrations (ug/mL)							
J. Fergusson, Drury	1347	436	135	1098	348	323	86
'Golden Special'	1201	539	128	1121	530	315	75
J. Stewart, Manukau	1180	258	119	946	259	211	72
Josette Howell	1257	371	141	1013	313	280	70
S. Kellam & P. Merten	1206	333	141	988	302	249	70
J.&W. Knoche, Wanganui	1161	357	153	1032	327	273	71
'Poorman's Orange'	1294	374	139	1121	350	302	96
L. Sorenson, Waitotara	1328	365	178	1021	317	290	86
Toi Street, Wanganui	1095	524	113	951	543	329	34
J. Trower, Matamata'	1270	313	116	1049	310	257	96
'Wheeny'	1110	519	83	959	446	335	36

Nar = naringin (*m/z* 579.171)
Nar-rut = narirutin (*m/z* 579.171)
Nar-glu = naringin glucoside (*m/z* 741.226)
Hes = hesperidin (*m/z* 609.181)
neoHes = neohesperidin (*m/z* 609.181)
Eri = eriocitrin (*m/z* 595.174)
Pon = poncirin (*m/z* 593.186)

4 References

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