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Phytochemical profile of commercially available food plant powders: their potential role in healthier food reformulations

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ABSTRACT

Reformulation of existing processed food or formulation of new foods using natural products (plant-based) will inherently confer to new products with less calories, fat, salt, phosphates and other synthetic components, and higher amounts of fibre, antioxidants, vitamins and other beneficial components. Plant ingredients, such as food plant powders, are currently being used in food manufacturing, predominantly for flavouring and colouring purposes. To expand their use as a food ingredient, freeze-dried powders representing major vegetable groups were characterised by targeted LC–MS/MS analysis of their phytochemicals. All the plant powders were found to be rich in flavonoids, phenolic acids and derivatives; total content in these compounds varied from around 130 mg kg^{-1} (green pea) to around 930 mg kg^{-1} (spinach). The food plant powders' phytochemical content represents valuable information for the food industry in the development of healthier novel foods and for the reformulation of existing food products in relation to antioxidants, food preservatives and alternatives to nitrite use.

1. Introduction

Food reformulation is defined as "changing the nutrient content of a processed food product to either reduce the content of negative nutrients, such as sodium, saturated fat, trans fat or energy (kilojoules), or to increase the content of beneficial nutrients, such as dietary fibre, wholegrain, fruit, vegetables and unsaturated fats" (NHFA, 2012). Reformulation of existing processed food or formulation of new foods using natural products (i.e. plant based ingredients) has the potential to confer several benefits; products lower in calories, fat, salt, phosphates and other synthetic components, and rich in fibre, antioxidants, and other bioactives. At the same time, the reformulation of processed foods provides a realistic opportunity to improve the health of a population by modifying the nutritional characteristics of commonly consumed processed foods (NHFA, 2012). The use of plant ingredients, such as food plant powders, by the food and drink industry is limited; therefore knowledge of their phytochemical content could be useful to expand their use as food ingredients.

Macronutrients, such as protein, fibre, carbohydrates (sugars) and fats, are essential for human health and are present in food products for reasons of nutrition and functionality. For example, vegetable proteins have been shown to play an important role in weight control and satiety similar to animal proteins (Neacsu, Fyfe, Horgan, & Johnstone, 2014). Functional properties of proteins include viscosity enhancement, water binding, gelation, aeration and foaming; and emulsification with consequent contributions to a food's flavour, texture and colour (Protein Trends & Technologies, 2013). Dietary fibre, the indigestible cell wall component of plant material, plays an important role in human diet and health (Smith & Tucker, 2011) for example ameliorating negative changes in gut fermentation seen with high protein diets (Russell et al., 2011). In the UK most people do not eat enough fibre (the average intake is 12.8 g/day for women and 14.8 g/day for men). The recommended average intake for adults is 18 g (non starch polysaccharides) per day (BNF, 2012). Thus, it is incumbent on the food industry to develop products with appropriate nutritional content particularly by lowering the fat and salt and by optimising minerals, vitamins and fibres (van Raaij, Hendriksen, & Verhagen, 2008).

Phytochemicals are compounds present in plants which are currently classified as non-nutrient constituents of the human diet. Among the most abundant are the phenolic acids and flavonoids. Phenolic acids are broadly distributed throughout the plant kingdom and they are attracting much scientific attention due to their potential bioactivity. For example, hydroxycinnamic acid was

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Table 1
Phytophenol content from food plant powders, concentration of benzoic acids (A); concentration of benzaldehydes, benzenes and acetophenones (B); concentration of cinnamic acids (C); concentration of phenylpropionic, phenylacetic, phenylpyruvic and phenyllactic acids (D); quinadilic acid, coniferyl alcohol, 4-hydroxy 3-methoxy ciannamyl alcohol, and 4-methylcatechol (E); catechins (F); lignans (G) and flavonoid, isoflavonoid and catechin content in the food plant powders (H).

	Red pepper		Spinach		Carrot		Yellow pea		Broccoli		Green pea		Swede		Beet root		Tomato		Celery		Onion	
	Free	Bound	Free	Bound	Free	Bound	Free	Bound	Free	Bound	Free	Bound	Free	Bound	Free	Bound	Free	Bound	Free	Bound	Free	Bound
A																						
Benzoic acid	5.22 ± 2.1	4.83 ± 0.59	3.48 ± 0.49	4.87 ± 0.55	1.47 ± 0.2	5.31 ± 0.52	1.57 ± 0.14	4.14 ± 1.13	1.44 ± 0.16	3.9 ± 0.92	1.60 ± 0.37	4.43 ± 0.85	1.02 ± 0.47	4.86 ± 0.49	1.28 ± 0.25	4.38 ± 0.65	1.94 ± 0.35	4.23 ± 0.6	1.22 ± 0.28	5.83 ± 0.5	1.21 ± 0.28	5.32 ± 0.57
Salicylic acid	0.24 ± 0.03	4.02 ± 0.67	1.27 ± 0.11	2.61 ± 0.32	0.01 ± 0.02	1.79 ± 0.34	n/d	1.02 ± 0.15	0.18 ± 0.3	3.02 ± 0.31	n/d	1.12 ± 0.16	n/d	2.39 ± 0.58	0.21 ± 0.37	1.19 ± 0.08	0.85 ± 0.05	3.48 ± 0.74	5.16 ± 0.8	13.31 ± 1.66	n/d	0.14 ± 0.14
m-Hydroxybenzoic acid	n/d	128.17 ± 42.15	n/d	n/d	n/d	109.68 ± 2.15	n/d	n/d	n/d	n/d	n/d	43.50 ± 38.84	n/d	97.60 ± 11.11	n/d	97.95 ± 22.44	n/d	99.99 ± 16.19	n/d	n/d	n/d	222.02 ± 15.81
p-Hydroxybenzoic acid	n/d	6.39 ± 0.6	1.87 ± 0.14	4.49 ± 0.46	2.82 ± 0.58	25.06 ± 2.78	2.41 ± 0.64	2.89 ± 0.47	n/d	3.36 ± 0.3	n/d	1.97 ± 0.22	n/d	1.7 ± 0.18	n/d	0.53 ± 0.05	n/d	6.87 ± 0.62	n/d	6.19 ± 1.52	n/d	1.35 ± 0.13
2,3-Dihydroxybenzoic acid	0.1 ± 0.01	0.64 ± 0.06	0.18 ± 0.01	0.1 ± 0.01	n/d	0.32 ± 0.07	n/d	n/d	n/d	0.36 ± 0.04	n/d	0.02 ± 0.04	0.09 ± 0.02	0.53 ± 0.05	n/d	0.08 ± 0.01	n/d	0.41 ± 0.05	0.03 ± 0	0.21 ± 0.02	n/d	0.2 ± 0.05
2,5-Dihydroxybenzoic acid	n/d	1 ± 0.16	2.66 ± 0.09	0.17 ± 0.3	n/d	0.55 ± 0.05	n/d	0.52 ± 0.06	n/d	3.08 ± 0.33	n/d	0.75 ± 0.03	n/d	2.03 ± 0.15	0.02 ± 0.04	0.41 ± 0.07	0.11 ± 0.01	8.82 ± 0.4	0.27 ± 0.06	5.79 ± 1.19	n/d	0.42 ± 0.08
Protocatechuic acid	4.95 ± 0.75	2.29 ± 0.19	1.3 ± 0.07	3.47 ± 2.07	1.45 ± 0.18	0.79 ± 0.12	1.49 ± 0.1	4.67 ± 0.29	0.26 ± 0.07	1.08 ± 0.1	0.33 ± 0.06	1.69 ± 0.12	0.39 ± 0.07	0.76 ± 0.05	0.36 ± 0.44	0.44 ± 0.11	1.59 ± 0.1	1.39 ± 0.03	0.2 ± 0.05	0.29 ± 0.02	2.84 ± 0.3	4.76 ± 0.57
2,4-Dihydroxybenzoic acid	n/d	0.09 ± 0.08	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	0.03 ± 0.03	n/d	0.32 ± 0.04	n/d	n/d
2,6-Dihydroxybenzoic acid	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	0.08 ± 0.01	n/d	n/d	n/d
o-Anisic acid	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	12.43 ± 0.47	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Gallic acid	0.25 ± 0.08	0.17 ± 0.05	0.15 ± 0.02	n/d	n/d	n/d	n/d	0.12 ± 0.02	n/d	n/d	n/d	n/d	n/d	n/d	0.06 ± 0.02	0.1 ± 0.03	0.02 ± 0.04	n/d	n/d	n/d	n/d	n/d
Vanillic acid	1.62 ± 0.03	6.55 ± 0.74	2.98 ± 0.07	5.46 ± 1	0.53 ± 0.03	6.76 ± 0.74	0.52 ± 0.01	1.05 ± 0.09	0.22 ± 0.06	2.04 ± 0.14	0.09 ± 0.01	1.28 ± 0.06	0.09 ± 0.02	2.07 ± 0.17	0.35 ± 0.07	4.61 ± 0.54	n/d	1.21 ± 0.13	0.54 ± 0.15	14.52 ± 2.01	0.19 ± 0.03	1.1 ± 0.16
Syringic acid	0.19 ± 0.02	0.52 ± 0.05	0.32 ± 0.03	0.18 ± 0.12	n/d	0.09 ± 0.03	n/d	0.13 ± 0.01	0.13 ± 0.04	0.37 ± 0.07	n/d	0.19 ± 0.02	0.03 ± 0.03	0.81 ± 0.12	0.31 ± 0.12	5.98 ± 0.67	0.01 ± 0.02	0.2 ± 0.03	n/d	0.07 ± 0	n/d	0.07 ± 0.07
3,4-Dimethoxybenzoic acid	n/d	n/d	22.3 ± 0.99	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
B																						
p-Hydroxybenzaldehyde	0.74 ± 0.15	1.37 ± 0.24	n/d	4.69 ± 0.32	0.19 ± 0.02	0.39 ± 0.15	0.29 ± 0.01	1.08 ± 0.24	0.37 ± 0.06	1.69 ± 0.22	0.55 ± 0.19	1.01 ± 0.1	n/d	0.80 ± 0.13	n/d	0.43 ± 0.08	n/d	0.93 ± 0.05	0.36 ± 0.04	2.81 ± 0.28	n/d	0.14 ± 0.05
Protocatachaldehyde	0.55 ± 0.08	1.47 ± 0.31	n/d	0.41 ± 0.08	0.3 ± 0.05	0.64 ± 0.09	0.25 ± 0.08	0.3 ± 0.08	0.11 ± 0.03	0.42 ± 0.04	0.04 ± 0.04	0.09 ± 0.02	0.53 ± 0.08	0.55 ± 0.11	0.49 ± 0.15	1.04 ± 0.23	0.04 ± 0.07	1.22 ± 0.08	0.08 ± 0.01	0.27 ± 0	n/d	0.16 ± 0.01
Vanillin	0.56 ± 0.54	0.85 ± 0.12	0.63 ± 0.38	1.88 ± 0.12	0.77 ± 0.43	0.79 ± 0.06	0.74 ± 0.06	0.41 ± 0.1	0.4 ± 0.28	0.74 ± 0.09	0.09 ± 0.02	0.47 ± 0.05	0.12 ± 0.02	1.06 ± 0.09	0.42 ± 0.13	1.28 ± 0.06	0.05 ± 0.01	0.71 ± 0.14	0.76 ± 0.12	3.47 ± 0.17	0.07 ± 0.01	2.11 ± 0.45
Syringin	0.07 ± 0.01	0.26 ± 0.05	0.01 ± 0.01	0.31 ± 0.06	0.01 ± 0.01	0.03 ± 0.02	0.02 ± 0	0.22 ± 0.06	0.28 ± 0.11	0.47 ± 0.05	0.01 ± 0.01	0.08 ± 0.01	0.04 ± 0	0.49 ± 0.08	0.02 ± 0.01	0.24 ± 0.06	n/d	0.04 ± 0.01	n/d.01	0.12 ± 0.01	n/d	0.03 ± 0.03
3-Methoxybenzaldehyde	n/d	0.71 ± 1.23	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	4.23 ± 0.17	1.76 ± 3.05	5.29 ± 1.51	n/d	4.32 ± 0.11	n/d	n/d	n/d	10.38 ± 0.1
Phenol	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	3.58 ± 0.81	n/d	10.34 ± 0.68	n/d	n/d	n/d	n/d	n/d	1.69 ± 1.65	n/d	8.36 ± 0.31
4-Ethylphenol	n/d	n/d	n/d	0.10 ± 0.03	n/d	n/d	n/d	0.02 ± 0.01	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
1,2-Hydroxybenzene	n/d	1.08 ± 0.13	n/d	n/d	0.18 ± 0.16	0.49 ± 0.14	0.1 ± 0.21	n/d	n/d	n/d	n/d	n/d	0.64 ± 0.09	0.35 ± 0.13	n/d	n/d	n/d	0.25 ± 0.04	n/d	n/d	n/d	n/d
1,2,3-Trihydroxybenzene	0.22 ± 0.38	0.43 ± 0.1	n/d	n/d	0.25 ± 0.24	n/d	0.25 ± 0.15	n/d	n/d	n/d	n/d	0.28 ± 0.07	n/d	0.35 ± 0.31	0.12 ± 0.2	0.13 ± 0.23	1.01 ± 0.03	0.13 ± 0.22	n/d	0.11 ± 0.19	n/d	n/d
Ellagic acid	n/d	n/d	n/d	n/d	n/d	0.13 ± 0.23	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
4-Hydroxyacetophenone	0.11 ± 0	0.26 ± 0.03	0.05 ± 0.01	0.55 ± 0.06	0.02 ± 0	0.08 ± 0.02	0.02 ± 0	0.06 ± 0.01	0.02 ± 0	0.08 ± 0.01	0.01 ± 0.01	0.08 ± 0.01	n/d.01	0.09 ± 0.02	0.03 ± 0.01	0.08 ± 0.01	0.05 ± 0.01	0.31 ± 0.01	0.21 ± 0.06	0.26 ± 0.03	0.16 ± 0.03	0.73 ± 0.09
4-Hydroxy-3-methoxyacetophenone	0.46 ± 0.22	1.31 ± 0.28	0.14 ± 0.06	0.6 ± 0.16	0.06 ± 0.02	0.07 ± 0.01	0.06 ± 0.03	0.16 ± 0.05	0.03 ± 0.03	0.35 ± 0.04	n/d	0.06 ± 0.01	n/d	0.11 ± 0.03	0.05 ± 0.04	0.46 ± 0.06	0.13 ± 0.01	0.77 ± 0.1	0.02 ± 0.03	0.3 ± 0.04	0.72 ± 0.12	3.41 ± 0.37
4-Hydroxy-3,5-dimethoxyacetophenone	0.12 ± 0.01	0.35 ± 0.03	0.28 ± 0.03	2.19 ± 0.15	n/d	n/d	n/d	0.14 ± 0.03	n/d	0.78 ± 0.08	n/d	0.05 ± 0.05	n/d	n/d	n/d	3.74 ± 0.45	n/d	0.13 ± 0.06	0.09 ± 0.01	0.10 ± 0.05	n/d	0.03 ± 0.04
3,4-Dimethoxyacetophenone	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	0.13 ± 0.02	n/d
C																						
Cinnamic acid	0.80 ± 0.11	1.82 ± 0.32	2.94 ± 0.25	1.68 ± 0.08	0.84 ± 0.2	1.54 ± 0.19	0.89 ± 0.12	1.41 ± 0.14	0.79 ± 0.1	1.48 ± 0.22	0.73 ± 0.11	1.48 ± 0.17	0.71 ± 0.13	0.90 ± 0.07	0.78 ± 0.2	1.46 ± 0.13	0.6 ± 0.19	1.18 ± 0.16	0.77 ± 0.04	1.01 ± 0.05	1.00 ± 0.09	0.96 ± 0.12
4-Methoxycinnamic acid	n/d	n/d	1.30 ± 0.12	0.55 ± 0.07	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
3,4,5-Trimethoxycinnamic acid	n/d	n/d	n/d	n/d	n/d	n/d	n/d	0.03 ± 0	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
o-Coumaric acid	n/d	5.86 ± 0.14	n/d	n/d	n/d	6.84 ± 0.29	n/d	n/d	n/d	n/d	n/d	5.48 ± 0.75	n/d	5.84 ± 0.43	n/d	8.17 ± 0.37	n/d	7.7 ± 0.7	n/d	6.67 ± 0.89	n/d	8.35 ± 1.17
p-Coumaric acid	n/d	9.65 ± 1.68	15.49 ± 0.76	53.69 ± 3.65	n/d	0.82 ± 0.21	0.43 ± 0	1.26 ± 0.35	n/d	7.48 ± 0.38	n/d	1.32 ± 0.28	n/d	n/d	1.79 ± 0.84	2.95 ± 0.73	4.28 ± 0.15	4.37 ± 0.35	n/d	0.84 ± 0.09	1.24 ± 0.04	0.27 ± 0.23
Caffeic acid	1.32 ± 0.07	8.51 ± 0.84	0.53 ± 0.04	1.49 ± 0.21	3.7 ± 0.36	14.01 ± 2.03	2.4 ± 0.23	0.63 ± 0.09	0.47 ± 0.09	27.93 ± 1.32	0.06 ± 0.05	0.21 ± 0.05	n/d	0.25 ± 0.03	1.12 ± 1.73	0.49 ± 0.12	5.61 ± 0.38	14.15 ± 0.68	0.65 ± 0.15	3.28 ± 0.36	0.12 ± 0.01	0.16 ± 0.17
Chlorogenic acid	17.90 ± 1.21	n/d	2.67 ± 0.59	n/d	148.11 ± 8.73	n/d	97.22 ± 10.69	n/d	4.93 ± 0.24	0.10 ± 0.04	0.15 ± 0.03	n/d	0.08 ± 0.01	n/d	6.18 ± 10.59	n/d	35.09 ± 1.87	n/d	9.60 ± 1.38	n/d	n/d	n/d
Ferulic acid	6.33 ± 0.3	26.1 ± 2.81	17.02 ± 0.13	135.27 ± 4.11	1.38 ± 0.15	0.78 ± 0.09	1.25 ± 0.11	5.77 ± 1.27	3.53 ± 0.87	50.83 ± 2.65	0.44 ± 0.05	1.34 ± 0.16	0.12 ± 0.03	0.55 ± 0.05	1.64 ± 0.46	208.18 ± 19.99	0.61 ± 0.06	2.18 ± 0.07	6.22 ± 1.64	6.56 ± 1.06	0.96 ± 0.09	2.28 ± 2.41
Ferulic dimer (5-5 linked)	n/d	n/d	0.04 ± 0	4.35 ± 0.35	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	0.06 ± 0.01	9.21 ± 2.34	n/d	n/d	n/d	n/d	n/d	0.03 ± 0.06
Ferulic dimer (8-8 linked)	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	0.06 ± 0.03	n/d	n/d	n/d	n/d	n/d	n/d
Hydrogenated ferulic dimer	0.15 ± 0.14	n/d	n/d	n/d	n/d	0.07 ± 0.01	n/d	n/d	n/d	n/d	n/d	0.06 ± 0.01	n/d	0.1 ± 0.01	n/d	0.1 ± 0.09	n/d	0.13 ± 0	n/d	n/d	n/d	0.43 ± 0.06
Sinapic acid	9.04 ± 0.23	36.64 ± 3.22	0.78 ± 0.03	1.24 ± 0.18	0.11 ± 0.02	0.34 ± 0.06	0.25 ± 0.03	14.91 ± 3.27	14.52 ± 1.69	228.15 ± 11.93	0.21 ± 0.02	1.81 ± 0.26	0.87 ± 0.19	3.60 ± 0.31	0.20 ± 0.11	1.78 ± 0.34	0.53 ± 0.02	1.76 ± 0.17	n/d	0.23 ± 0.04	0.67 ± 0.11	0.87 ± 0.05
3,4-Dimethoxycinnamic acid	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	0.95 ± 0.03	n/d	n/d	n/d	n/d	n/d	0.04 ± 0	n/d	n/d	n/d	n/d	n/d	n/d
D																						
Phenylpropionic acid	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	2.20 ± 0.17	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
4-Hydroxyphenylpropionic acid	n/d	2.32 ± 0.35	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	6.60 ± 0.2	n/d	n/d	n/d	2.01 ± 0.65
4-Hydroxy 3-methoxyphenylpropionic acid	0.25 ± 0.02	0.23 ± 0.03	0.11 ± 0.02	0.11 ± 0.09	0.08 ± 0.01	0.23 ± 0.02	0.07 ± 0	0.22 ± 0.03	0.12 ± 0.02	0.11 ± 0.01	n/d	0.19 ± 0.03	n/d	n/d	0.05 ± 0.09	0.22 ± 0.04	0.32 ± 0.03	3.95 ± 0.25	0.08 ± 0.01	0.36 ± 0.09	0.02 ± 0.03	0.13 ± 0.01
3-Hydroxyphenylpropionic acid	n/d	n/d	n/d	0.23 ± 0.01	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
3,4-Dihydroxyphenylacetic acid	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	0.58 ± 0.14	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Phenylacetic acid	2.93 ± 0.42	1.03 ± 0.13	6.35 ± 0.04	0.9 ± 0.15	0.81 ± 0.16	0.88 ± 0.11	0.77 ± 0.22	0.79 ± 0.1	1.13 ± 0.04	0.92 ± 0.16	0.89 ± 0.06	0.83 ± 0.06	0.73 ± 0.03	0.74 ± 0.09	0.73 ± 0.04	0.63 ± 0.11	0.76 ± 0.04	0.97 ± 0.13	0.84 ± 0.24	0.83 ± 0.14	0.29 ± 0.07	0.46 ± 0.05
3-Hydroxyphenylacetic acid	n/d	2.05 ± 0.39	2.33 ± 0.12	n/d	n/d	1.43 ± 0.29	n/d	n/d	n/d	n/d	n/d	0.72 ± 0.04	n/d	0.94 ± 0.24	n/d	0.83 ± 0.24	n/d	2.09 ± 0.16	n/d	0.72 ± 0.13	n/d	0.81 ± 0.06
3,4-Dihydroxymandelic acid	n/d	0.67 ± 0.09	0.13 ± 0.12	0.16 ± 0.02	0.28 ± 0.02	0.7 ± 0.09	0.19 ± 0.03	n/d	0.1 ± 0.09	0.35 ± 0.08	n/d	0.1 ± 0.09	n/d	0.43 ± 0.06	0.1 ± 0.09	n/d	0.1 ± 0.09	0.17 ± 0.03	n/d	n/d	n/d	n/d
Phenylpyruvic acid	0.42 ± 0.72	4.03 ± 0.21	1.87 ± 0.23	17.79 ± 3.99	2.35 ± 0.12	3.95 ± 0.42	2.38 ± 0.15	3.5 ± 0.33	1.04 ± 0.11	4.19 ± 0.33	2.31 ± 0.59	4.49 ± 0.12	1.56 ± 0.23	4.08 ± 0.43	1.45 ± 0.06	4.54 ± 0.46	2.93 ± 0.24	6.19 ± 0.57	2.16 ± 0.35	4.51 ± 0.26	1.84 ± 0.03	5.06 ± 0.38
4-Hydroxyphenylpyruvic acid	34.99 ± 3.64	163.44 ± 29.03	442.07 ± 77.6	37.29 ± 11.91	43.65 ± 8.63	61.98 ± 21.59	27.59 ± 3.67	10.18 ± 2.42	7.90 ± 1.8	22.05 ± 2.87	6.06 ± 1.32	24.95 ± 7.56	50.31 ± 4.84	68.78 ± 7.28	21.16 ± 2.61	8.57 ± 2.51	74.55 ± 5.69	89.19 ± 38.13	8.51 ± 0.56	26.77 ± 8.71	7.89 ± 1.5	100.36 ± 83.6
Phenyllactic acid	2.26 ± 0.49	0.44 ± 0.06	0.41 ± 0.04	0.54 ± 0.07	1.65 ± 0.11	0.22 ± 0.04	1.67 ± 0.15	0.25 ± 0.05	0.19 ± 0.03	0.17 ± 0.03	0.69 ± 0.25	0.28 ± 0.05	0.12 ± 0.03	0.24 ± 0.05	0.16 ± 0.01	0.23 ± 0.06	0.67 ± 0.08	0.29 ± 0.06	0.58 ± 0.14	1.06 ± 0.19	0.15 ± 0.04	0.4 ± 0.08
4-Hydroxyphenyllactic cid	n/d	1.55 ± 0.17	n/d	0.07 ± 0.12	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	0.62 ± 0.09	2.76 ± 0.15	0.63 ± 0.14	4.68 ± 1.47	n/d	n/d