

Turmeric survey

Results available: Results available

Area of research interest: [Chemical hazards in food and feed](#)

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Background to the study

The consumption of turmeric supplements is increasingly popular and is reported to provide numerous health benefits including antioxidant, analgesic, anti-inflammatory, antiseptic, anticarcinogenic, chemopreventive, chemotherapeutic, antiviral, antibacterial, antifungal and antiplatelet activities [1]. However, in recent months there has been a number of reports of hepatotoxicity linked to the consumption of these supplements. Such reports and scientific publications led to a review of the safety of turmeric and curcumin by the UK Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT). The statement issued by COT in November 2019 concluded “Given past reported contamination issues with turmeric supplements, the Committee concluded that there would be value in commissioning a chemical analysis of turmeric supplements and raw/powdered turmeric available on the UK market”. To address this conclusion the FSA requested Fera to:

- develop and validate in-house method(s) for measuring curcumin in turmeric containing supplements, ground/powdered turmeric and raw/fresh turmeric
- develop and validate in-house a method for measuring piperine in turmeric containing supplements
- purchase turmeric containing supplements (n=15), ground/powdered turmeric (n=10) and raw/fresh turmeric (n=5) from a mixture of local outlets and over the internet
- analyse all 30 samples for trace elements and curcumin
- analyse all supplement samples for piperine content.

Methodology

2.1 Samples

Samples were collected from retail outlets in the north of England and via the internet in February 2021. In accordance with the FSA's request the turmeric containing supplements (n = 15), ground/powdered turmeric (n = 10) and raw/fresh turmeric (n = 5) were purchased from a mixture of providers, for example, retail outlets and the internet. Sample details were recorded and the associated packaging material was photographed.

2.2 Sample preparation for trace element analysis

2.2.1 Fresh turmeric

The fresh turmeric samples were washed with Millipore water, chopped with ceramic knife on a plastic board, then blended using a Buchi B400 Blender fitted with ceramic blades. 20 g of each homogenised samples was transferred to an acid cleaned vessel prior to trace element extraction and analysis.

2.2.2 Ground turmeric

The ground turmeric samples were mixed in the container in which they were received. Replicate aliquots were removed directly for trace element analysis.

2.2.3 Turmeric supplements

Tablets – a portion of a tablet, an entire tablet or a number of intact tablets (depending on tablet mass) were removed directly for trace element analysis. Capsules - an entire capsule was removed directly for trace element analysis.

2.3 Trace element analysis

2.3.1 Sample extraction

Three sub-samples (3 x 0.5-1.0 g) of each turmeric survey sample were placed directly into TFM microwave digestion tubes and digested in a mixture of nitric acid and hydrochloric acid using a high-pressure microwave digestion system (Milestone UltraWave).

2.3.2 Inductively coupled plasma (ICP) – mass spectrometry (MS) analysis

Samples were analysed on an Agilent 7700x ICP – mass spectrometer fitted with an ASX-500 auto-sampler and a standard front end, consisting of nickel cones, a glass double-pass spray chamber and a glass concentric nebuliser. The analysis was conducted with a collision cell

operated in both “no gas” and helium mode, the latter to remove any interferences. The instrument was operated in general purpose mode with carrier gas flow 1.0 L/minute, RF power 1550 W, sampling depth 10 mm, peri-pump speed 0.1 rps. Concentrations of the following elements were determined: Ag - silver, Al - aluminium, As - arsenic, Ba - barium, Be - beryllium, Bi - bismuth, Ca - calcium, Cd - cadmium, Ce - cerium, Co - cobalt, Cr - chromium, Cs - caesium, Cu - copper, Dy - dysprosium, Er - erbium, Eu - europium, Fe - iron, Ga - gallium, Gd - gadolinium, Ge - germanium, Hg - mercury, Ho - holmium, K - potassium, La - lanthanum, Lu - lutetium, Mg - magnesium, Mn - manganese, Mo - molybdenum, Na - sodium, Nd - neodymium, Ni - nickel, P - phosphorus, Pb - lead, Pr - praseodymium, Rb - rubidium, S - sulphur, Sb - antimony, Se - selenium, Sm - samarium, Sn - tin, Sr - strontium, Tb - terbium, Tl - thallium, Tm - thulium, U - uranium, V - vanadium, Yb - ytterbium, Zn - zinc, Hf - Hafnium, Ir - Iridium, Nb - Niobium, Os - Osmium, Pd - Palladium, Pt - Platinum, Re - Rhenium, Ru - Ruthenium, Sc - Scandium, Ta - Tantalum, Te - Tellurium, Th - Thorium, Ti - Titanium, W - Tungsten, Y - Yttrium. Quality checks included blanks, spikes, and certified reference materials (CRMs). The methodology used is accredited to ISO17025.

2.4 Method development and validation – curcumin in turmeric containing supplements, ground/powdered turmeric and raw/fresh turmeric

Methodology was identified which allowed for the determination of the curcuminoids: curcumin, bisdemethoxycurcumin (BDMC) and demethoxycurcumin (DMC) (Figure 1) [3]. This methodology was established in-house with additional confirmatory analytical capability using Time-of-Flight (TOF) mass spectrometry (MS). In short, the method involved: extraction of the dried sample 0.5 g with tetrahydrofuran (10 mL) by shaking overnight at ambient temperature. The samples were then diluted 1,000 fold with methanol before a portion (1 mL) was evaporated to dryness under nitrogen. The residue was over-spiked and reconstituted in methanol to a total volume of 1mL prior to analysis by reverse phase HPLC using an ACE3 C18-AR 2.1 mm id x 100 mm, LC column with diode array (DAD - the quantitation wavelength was 425 nm) and TOF-MS detection. The mobile phase was 1.275% formic acid and methanol. The limit of quantification (LOQ) was determined using the measured concentration for the lowest calibration standard equivalent to the 1,000 fold diluted sample (0.00005 g/mL).

Replicate (n = 7 at each concentration) spiked samples following dilution (spiked to achieve concentrations of 0.45, 4.5 and 9 µg/mL in the solution equivalent to 9,000, 90,000 and 180,000 mg/kg in the samples) were prepared using lyophilised root ginger as a blank matrix. The method validation was performed in replicate (n=3) and the method performance characteristics determined.

2.5 Sample preparation for curcumin, bisdemethoxycurcumin and demethoxycurcumin analysis

2.5.1 Fresh turmeric

The fresh turmeric samples were washed with Millipore water, chopped with ceramic knife on a plastic board, then blended using a Buchi B400 blender fitted with ceramic blades. The blended sample was lyophilised using an Edwards pirani freeze dryer. The samples were mixed, and replicate aliquots were taken for analysis.

2.5.2 Ground turmeric

The ground turmeric samples were mixed in the container in which they were received. Replicate aliquots were taken for analysis.

2.5.3 Turmeric supplements

Tablets – Five tablets (of each type) were ground using a pestle and mortar. Replicate aliquots were taken for analysis. Capsules - Five capsule were emptied, then mixed. Replicate aliquots were taken for analysis.

2.6 Curcumin, bisdemethoxycurcumin and demethoxycurcumin analysis

2.6.1 Sample extraction

Duplicate aliquots (0.5 g) of each prepared sample were placed in amber vials (12 mL) and capped. Tetrahydrofuran (10 mL) was added, sonicated (10 mins) then shaken overnight at ambient temperature. The samples were allowed to settle (2 hrs, 4°C) then diluted 1,000 fold with methanol before a portion (1 mL) was aliquoted to a 2 mL vial and capped.

2.6.2 Standard preparation

Standards were prepared using lyophilised ginger extracted using the above procedure. A portion of the extract (1 mL) was evaporated to dryness under nitrogen. The residue was over-spiked with curcumin, bisdemethoxycurcumin and demethoxycurcumin at levels equivalent to 0, 0.1, 0.25, 0.5, 1, 2.5, 5 and 10 µg/mL and reconstituted in methanol to a total volume of 1mL.

2.6.3 LC-TOF-MS analysis

Portions of the solvent extracts of the samples and standards were analysed using an Agilent 1200 liquid chromatograph coupled with an Agilent 6230 TOF. Chromatographic separation was achieved on an ACE3 C18-AR 2.1 mm id x 100 mm held at 60°C. The mobile phases comprised of water containing 1.275% formic acid (A) and methanol (B). The gradient started at 20% B and changed to 100% B at 15 minutes before returning to 20% B at 20 minutes. The flow rate was 0.4 mL/minute and the injection volume was 10 µL. The MS was operated in positive ESI mode with monitoring from 50 – 1600 m/z. Spectral data were acquired by diode array and the quantitation wavelength was 425 nm.

2.7 Method development – piperine in turmeric containing supplements

Methodology was identified in house which allowed for the determination of piperine. This methodology was established in-house using Time-of-Flight (TOF) mass spectrometry (MS). In short, the method involved: extraction of the dried sample 0.5 g with tetrahydrofuran (10 mL) by shaking overnight at ambient temperature. The samples were then diluted 1,000 fold with methanol before a portion (1 mL) was evaporated to dryness under nitrogen. The residue was over-spiked and reconstituted in methanol (1 mL) prior to analysis by reverse phase HPLC using an ACE3 C18-AR 2.1 mm id x 100 mm, LC column with TOF-MS detection. The mobile phase was 1.275% formic acid and methanol. The limit of quantification (LOQ) was determined using the measured concentration for the lowest calibration standard equivalent to the 1,000 fold diluted sample (0.00005 g/mL).

Replicate (n = 7 at each concentration) spiked samples following dilution (spiked to achieve concentrations of 0.045 and 0.9 µg/mL in the solution equivalent to 900 and 18,000 mg/kg in the samples) were prepared using lyophilised root ginger as a blank matrix. The method validation was performed in replicate (n = 3) and the method performance characteristics determined.

2.8 Sample preparation for piperine analysis

2.8.1 Fresh turmeric

The fresh turmeric samples were washed with Millipore water, chopped with ceramic knife on a plastic board, then blended using a Buchi B400 blender fitted with ceramic blades. The blended sample was lyophilised using an Edwards pirani freeze dryer. The samples were mixed, and replicate aliquots were taken for analysis.

2.8.2 Ground turmeric

The ground turmeric samples were mixed in the container in which they were received. Replicate aliquots were taken for analysis.

2.8.3 Turmeric supplements

Tablets – Five tablets (of each type) were ground using a pestle and mortar. Replicate aliquots were taken for analysis. Capsules - Five capsule were emptied, then mixed. Replicate aliquots were taken for analysis.

2.9 Piperine analysis

2.9.1 Sample extraction

Duplicate aliquots (0.5 g) of each prepared sample were placed in amber vials (12 mL) and capped. Tetrahydrofuran (10 mL) was added, sonicated (10 minutes) then shaken overnight at ambient temperature. The samples were allowed to settle (2 hrs, 4°C) then diluted 1,000 fold with methanol before a portion (1 mL) was aliquoted to a 2 mL vial and capped.

2.9.2 Standard preparation

Standards were prepared using lyophilised ginger extracted using the above procedure. A portion of the extract (1 mL) was evaporated to dryness under nitrogen. The residue was over-spiked with piperine at levels equivalent to 0, 0.01, 0.025, 0.05, 0.1, 0.25, 0.5 and 1 µg/mL and reconstituted in methanol to a total volume of 1 mL.

2.9.3 LC-TOF-MS analysis

Portions of the solvent extracts were analysed using an Agilent 1200 liquid chromatograph coupled with an Agilent 6230 TOF. Sample extracts were diluted as required. Chromatographic separation was achieved on an ACE3 C18-AR 2.1 mm id x 100 mm held at 60°C. The mobile phases comprised of water containing 1.275% formic acid (A) and methanol (B). The gradient started at 20% B and changed to 100% B at 15 minutes before returning to 20% B at 20 minutes. The flow rate was 0.4 mL/minute and the injection volume was 10 µL. The MS was operated in positive ESI mode with monitoring from 50 – 1600 m/z. Quantitation was carried out using m/z 286.1438 ± 100 ppm.

Results

3.1 Sampling

Samples were receipted into the laboratory by logging into the Fera Laboratory Information Management System (LIMS). Each sample was assigned a unique number. Sample details are given in Table 1.

3.2 Trace element analysis

The concentrations of the elements determined in the samples are provided in Table 2. Quality assurance data is provided in Annex 1.

3.3 Curcumin, bisdemethoxycurcumin and demethoxycurcumin method development and validation

Method performance data is provided in Annex 2.

3.4 Curcumin, bisdemethoxycurcumin and demethoxycurcumin analysis

The concentrations of curcumin, bisdemethoxycurcumin and demethoxycurcumin determined in the samples are provided in Table 3. Concentrations are reported in units of mg/kg as received for the fresh, ground and supplements in tablet form. For the supplement capsules the powder was removed from the capsule and tested and so the concentrations are reported in units of mg/kg of the powder content. The mass of the powder in the capsule is also provided, as well as the mass of the tablet for those in tablet form. For the lyophilised fresh samples both the dry weight concentration and the equivalent wet weight concentrations have been reported.

3.5 Piperine method development and validation

Method performance data is provided in Annex 3.

3.6 Piperine analysis

The concentrations of piperine determined in the samples are provided in Table 4.

Concentrations are reported in units of mg/kg as received for the fresh, ground and supplements in tablet form. For the supplement capsules the powder was removed from the capsule and tested and so the concentrations are reported in units of mg/kg of the powder content. The mass of the powder in the capsule is also provided, as well as the mass of the tablet for those in tablet form. Samples TU06, TU07 TU12, TU17, TU21 and TU30 contained levels above the calibration range and were diluted 10 fold to obtain quantitative data.

Annex 1: Trace element quality assurance data

Download a full copy of the tables in

ODT

[View Annex 1: Trace element quality assurance data tables as ODT\(Open in a new window\)](#)
(40.89 KB)

Recovery and limit of detection

Element	Recovery (%)	LoD (mg/kg)
Lithium	91	0.005
Beryllium	98	0.001
Boron	71	1
Sodium	57	5
Magnesium	100	1
Aluminium	64	0.5
Silicon	98	100
Phosphorus	95	10
Sulfur	90	500
Potassium	78	20
Calcium	81	5
Scandium	77	0.005
Titanium	55	0.1
Vanadium	67	0.01
Chromium	100	0.05
Manganese	100	0.1
Iron	100	1
Cobalt	100	0.005
Nickel	100	0.05
Copper	100	0.05
Zinc	100	0.2
Gallium	80	0.01
Germanium	80	0.01
Arsenic	110	0.005
Selenium	100	0.01
Rubidium	107	0.02
Strontium	95	0.02
Yttrium	91	0.001
Zirconium	89	0.01

Element	Recovery (%)	LoD (mg/kg)
Niobium	85	0.002
Molybdenum	90	0.02
Ruthenium	93	0.001
Rhodium	91	0.005
Palladium	89	0.005
Silver	75	0.01
Cadmium	90	0.005
Tin	99	0.005
Antimony	101	0.002
Tellurium	129	0.01
Caesium	128	0.001
Barium	109	0.02
Lanthanum	111	0.001
Cerium	105	0.001
Praseodymium	100	0.001
Neodymium	95	0.001
Samarium	95	0.001
Europium	95	0.001
Gadolinium	95	0.001
Terbium	90	0.001
Dysprosium	88	0.001
Holmium	88	0.001
Erbium	85	0.001
Thulium	87	0.001
Ytterbium	87	0.001
Lutetium	84	0.001
Hafnium	69	0.001
Tantalum	66	0.001
Tungsten	79	0.002
Rhenium	89	0.001
Osmium	90	0.005
Iridium	87	0.001
Platinum	97	0.001
Gold	90	0.002
Mercury	95	0.005
Thallium	96	0.005
Lead	94	0.005
Bismuth	101	0.001
Thorium	89	0.001
Uranium	94	0.001

Certified reference materials

Element	NIST 1548a (mg/kg)	Reference (mg/kg)	Bias (%)	INCT-OBTL-5 (mg/kg)	Reference (mg/kg)	Bias (%)	ZC73012(mg/kg)	Reference(mg/kg)	Bias (%)
Lithium	0.028	None	-	29.1	~19.3	51	0.496	0.54	-8
Beryllium	<0.001	None	-	0.085	~0.081	5	0.002	~0.002	21
Boron	4.55	4.16	9	50	33.6	49	26.9	19.6	37
Sodium	7470	8130	-8	407	~435	-7	12900	10900	18

Element	NIST 1548a (mg/kg)	Reference (m g/kg)	Bias (%)	INCT-OBTL- 5 (mg/kg)	Reference (m g/kg)	Bias (%)	ZC73012(mg/ kg)	Reference(m g/kg)	Bias (%)
Magnesium	325	580	-44	8810	8530	3	1690	2410	-30
Aluminium	79	72.4	9	3150	1980	59	130	166	-22
Silicon	<100	~78.7	-53	2280	None	-	<100	240	-74
Phosphorus	2920	3490	-16	1720	1700	1	4670	4600	1
Sulfur	1500	1930	-22	4840	4550	6	7320	7200	2
Potassium	6360	6970	-9	31500	22700	39	18200	15500	17
Calcium	1610	1970	-18	51600	40000	29	7010	7000	0
Scandium	<0.005	~0.0008	-	0.782	0.64	22	0.009	~0.007	29
Titanium	5.8	~4.7	23	199	~80.7	146	5.6	~9	-38
Vanadium	0.02	None	-	6.41	4.01	60	0.05	~0.11	-59
Chromium	0.05	None	-	6.27	~6.3	0	1.62	1.8	-10
Manganese	3.5	5.75	-39	191	180	6	13.8	18.7	-26
Iron	20	35.3	-42	1630	~1490	9	68	98	-30
Cobalt	0.01	~0.028	-63	0.919	0.981	-6	0.056	0.089	-37
Nickel	0.24	0.37	-35	8.21	8.5	-3	0.98	0.93	6
Copper	1.43	2.32	-38	9.64	10.1	-5	1.5	2.7	-44
Zinc	16.7	24.6	-32	51.9	52.4	-1	28.6	26	10
Gallium	0.01	None	-	0.92	None	-	0.03	None	-
Germanium	<0.01	None	-	0.17	None	-	0.02	~0.004	421
Arsenic	0.195	0.2	-3	0.766	0.668	15	0.068	0.062	10
Selenium	0.23	0.25	-7	0.18	None	-	0.23	0.2	16
Rubidium	3.78	None	-	17.6	19.1	-8	20.4	19.6	4
Strontium	2.76	2.93	-6	116	105	11	52.4	48	9
Yttrium	0.003	None	-	1.31	~0.963	36	0.012	0.015	-19
Zirconium	0.05	None	-	0.88	None	-	0.04	None	-
Niobium	0.002	None	-	0.196	None	-	0.012	~0.014	-12
Molybdenum	0.22	0.26	-16	0.41	0.414	-2	0.77	0.71	8
Ruthenium	<0.001	None	-	<0.001	None	-	<0.001	None	-
Rhodium	<0.005	None	-	<0.005	None	-	<0.005	None	-
Palladium	<0.005	None	-	0.058	None	-	0.024	None	-
Silver	<0.01	Noe	-	0.05	0.053	-3	0.09	None	-
Cadmium	0.034	0.035	-4	3.31	2.64	25	0.046	0.035	32
Tin	14.7	17.2	-15	0.163	None	-	0.008	None	-
Antimony	0.0078	~0.009	-14	0.059	0.076	-21	0.008	None	-
Tellurium	<0.01	None	-	<0.01	None	-	<0.01	None	-
Caesium	0.0087	None	-	0.242	0.288	-16	0.082	0.082	0
Barium	1.08	1.1	-2	64.1	67.4	-5	34.2	12	185
Lanthanum	0.003	None	-	1.48	1.69	-13	0.02	0.024	-15
Cerium	0.004	0.01	-56	2.82	2.99	-6	0.043	0.044	-1
Praseodymiu m	0.001	None	-	0.37	~0.321	15	0.005	0.004	11
Neodymium	0.003	None	-	1.47	1.33	10	0.017	0.015	11
Samarium	0.001	None	-	0.29	0.264	10	0.017	0.015	-2
Europium	<0.001	None	-	0.065	0.06	7	0.005	~0.004	28
Gadolinium	0.001	None	-	0.268	~0.243	10	0.003	0.003	-17
Terbium	<0.001	None	-	0.043	0.035	24	<0.001	~0.0005	-
Dysprosium	<0.001	None	-	0.246	~0.184	33	0.002	0.003	-13

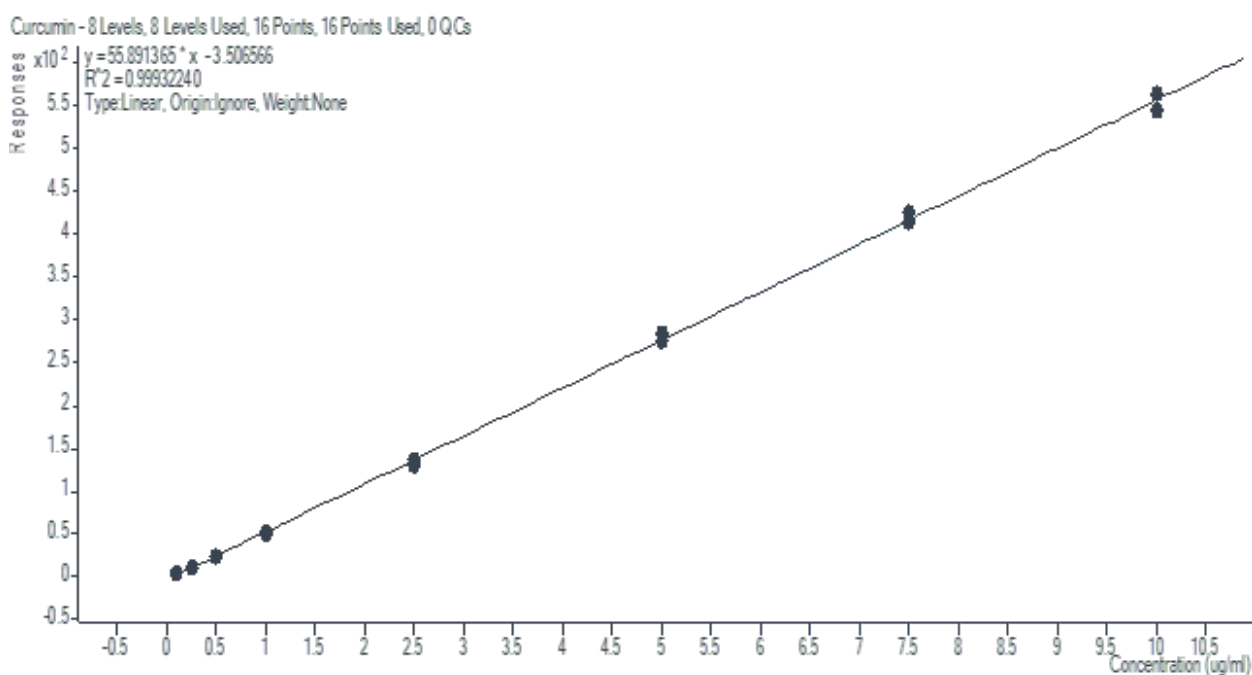
Element	NIST 1548a (mg/kg)	Reference (m g/kg)	Bias (%)	INCT-OBTL- 5 (mg/kg)	Reference (m g/kg)	Bias (%)	ZC73012(mg/ kg)	Reference(m g/kg)	Bias (%)
Holmium	<0.001	None	-	0.048	~0.035	39	<0.001	~0.0005	-
Erbium	<0.001	None	-	0.14	0.101	38	0.002	~0.001	14
Thulium	<0.001	None	-	0.019	~0.014	39	<0.001	~0.00023	-
Ytterbium	<0.001	None	-	0.119	0.115	3	0.002	0.001	5
Lutetium	<0.001	None	-	0.018	~0.017	6	<0.001	~0.00016	-
Hafnium	0.002	None	-	0.034	0.291	-88	0.001	None	-
Tantalum	<0.001	None	-	0.01	0.042	-75	0.001	None	-
Tungsten	0.002	None	-	0.05	None	-	0.061	None	-
Rhenium	<0.001	None	-	0.01	None	-	0.001	None	-
Osmium	<0.005	None	-	<0.005	None	-	<0.005	None	-
Iridium	<0.001	None	-	<0.001	None	-	<0.001	None	-
Platinum	<0.001	None	-	<0.001	None	-	<0.001	None	-
Gold	<0.002	None	-	0.003	~0.003	-4	<0.002	None	-
Mercury	<0.005	~0.005	-49	0.018	0.021	-13	0.011	0.011	-2
Thallium	<0.005	None	-	0.064	0.051	24	0.006	~0.006	-4
Lead	0.054	0.044	22	2.16	2.01	8	0.274	0.19	44
Bismuth	0.001	None	-	0.115	None	-	0.001	0.003	-52
Thorium	0.001	None	-	0.519	0.503	3	0.006	0.009	-38
Uranium	0.002	None	-	0.106	~0.113	-6	0.021	0.02	7

'-' indicates values where they are issued as a reference value.

Annex 2: Curcuminoid validation data

Curcumin

Calibration



Recovery and repeatability

Sample	Batch 1 concentration (mg/kg)	Batch 2 concentration (mg/kg)	Batch 3 concentration (mg/kg)
Low spike sample 1	9,899	9,217	9,203
Low spike sample 2	8,983	9,617	9,093
Low spike sample 3	8,531	8,906	9,180
Low spike sample 4	8,612	8,853	9,416
Low spike sample 5	8,716	8,632	9,816
Low spike sample 6	8,657	9,230	9,688
Low spike sample 7	8,631	8,703	9,695
Average	8,861	9,023	9,442
Recovery	98%	98%	105%
Repeatability (RSD)	5.4%	1.1%	3.1%
Medium spike sample 1	88,083	88,309	90,267
Medium spike sample 2	86,934	88,557	89,552
Medium spike sample 3	86,023	86,293	87,761

Sample	Batch 1 concentration (mg/kg)	Batch 2 concentration (mg/kg)	Batch 3 concentration (mg/kg)
Medium spike sample 4	86,003	87,335	89,793
Medium spike sample 5	88,285	89,001	89,365
Medium spike sample 6	90,875	88,664	90,956
Medium spike sample 7	90,134	88,336	90,049
Average	88,048	88,071	89,678
Recovery	98%	98%	100%
Repeatability (RSD)	2.2%	1.1%	1.1%
High spike sample 1	180,540	178,114	179,583
High spike sample 2	183,548	180,893	182,099
High spike sample 3	180,048	178,661	183,678
High spike sample 4	178,903	176,628	178,446
High spike sample 5	178,456	176,339	175,942
High spike sample 6	178,537	176,395	177,756
High spike sample 7	176,755	175,586	180,721
Average	179,541	177,516	179,747
Recovery	100%	99%	100%
Repeatability (RSD)	1.2%	1.0%	1.5%

Bisdemethoxycurcumin

Calibration

Recovery and repeatability

Sample	Batch 1 concentration (mg/kg)	Batch 2 concentration (mg/kg)	Batch 3 concentration (mg/kg)
Low spike sample 1	10,055	8,642	9,529
Low spike sample 2	9,389	9,076	9,542
Low spike sample 3	9,583	8,575	9,586
Low spike sample 4	9,356	8,941	9,199

Sample	Batch 1 concentration (mg/kg)	Batch 2 concentration (mg/kg)	Batch 3 concentration (mg/kg)
Low spike sample 5	9,644	8,630	9,546
Low spike sample 6	9,632	9,064	9,433
Low spike sample 7	9,675	8,492	9,603
Average	9,619	8,774	9,491
Recovery	107%	97%	105%
Repeatability (RSD)	2.4%	2.8%	1.5%
Medium spike sample 1	84,061	90,443	87,706
Medium spike sample 2	83,835	91,551	89,092
Medium spike sample 3	85,270	92,213	86,301
Medium spike sample 4	87,098	90,044	87,764
Medium spike sample 5	85,970	90,827	90,689
Medium spike sample 6	88,088	92,214	89,824
Medium spike sample 7	85,824	93,060	89,137
Average	85,724	91,662	88,645
Recovery	95%	102%	98%
Repeatability (RSD)	1.8%	1.4%	1.7%
High spike sample 1	181,848	185,629	179,314
High spike sample 2	185,518	191,136	182,990
High spike sample 3	182,230	190,187	181,666
High spike sample 4	182,972	185,342	180,509
High spike sample 5	182,480	186,815	182,336
High spike sample 6	181,894	180,271	182,455
High spike sample 7	182,171	183,198	184,728
Average	182,730	186,083	182,000
Recovery	102%	103%	101%
Repeatability (RSD)	0.7%	2.0%	1.0%

Demethoxycurcumin

Calibration

Recovery and repeatability

Sample	Batch 1 concentration (mg/kg)	Batch 2 concentration (mg/kg)	Batch 3 concentration (mg/kg)
Low spike sample 1	11,016	8,567	9,527

Sample	Batch 1 concentration (mg/kg)	Batch 2 concentration (mg/kg)	Batch 3 concentration (mg/kg)
Low spike sample 2	10,113	8,704	9,472
Low spike sample 3	10,173	8,156	9,239
Low spike sample 4	9,957	8,663	8,534
Low spike sample 5	10,611	7,909	9,457
Low spike sample 6	10,452	8,168	9,463
Low spike sample 7	10,327	7,999	9,476
Average	10,378	8,309	9,310
Recovery	115%	92%	103%
Repeatability (RSD)	3.4%	4.0%	3.8%
Medium spike sample 1	82,492	90,081	87,906
Medium spike sample 2	91,684	91,188	90,377
Medium spike sample 3	90,315	88,761	86,577
Medium spike sample 4	90,267	90,235	87,702
Medium spike sample 5	87,640	88,703	88,382
Medium spike sample 6	90,271	90,246	91,100
Medium spike sample 7	87,736	91,431	88,961
Average	88,629	90,105	88,715
Recovery	98%	100%	99%
Repeatability (RSD)	3.5%	1.2%	1.8%
High spike sample 1	177,896	180,299	177,926
High spike sample 2	180,907	184,294	179,632
High spike sample 3	181,684	185,411	182,946
High spike sample 4	177,627	182,840	177,503
High spike sample 5	183,585	186,984	176,702
High spike sample 6	180,224	175,844	170,056
High spike sample 7	179,451	181,837	179,465
Average	180,196	182,501	177,747
Recovery	100%	101%	99%
Repeatability (RSD)	1.2%	2.0%	2.2%

Annex 3: Piperine validation data

Piperine

Calibration

Recovery and repeatability

Sample	Batch 1 concentration (mg/kg)	Batch 2 concentration (mg/kg)	Batch 3 concentration (mg/kg)
Low spike sample 1	633	766	820
Low spike sample 2	581	743	831
Low spike sample 3	623	702	754
Low spike sample 4	588	741	818
Low spike sample 5	633	738	809
Low spike sample 6	599	702	814
Low spike sample 7	620	688	758
Average	611	726	801
Recovery	68%	81%	89%
Repeatability (RSD)	3.5%	3.9%	3.9%
Medium spike sample 1	16,327	14,128	12,387
Medium spike sample 2	15,272	13,283	12,466
Medium spike sample 3	16,045	11,923	11,436
Medium spike sample 4	15,890	12,224	12,300
Medium spike sample 5	15,569	11,036	12,633
Medium spike sample 6	15,362	10,935	12,868
Medium spike sample 7	16,604	11,152	12,420
Average	15,867	12,097	12,359
Recovery	88%	67%	69%

Sample	Batch 1 concentration (mg/kg)	Batch 2 concentration (mg/kg)	Batch 3 concentration (mg/kg)
Repeatability (RSD)	3.1%	10.1%	3.6%

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Figure 1: Curcuminoid structures

Table 1: Sample details

Sample code	LIMS number	Product	Type of product
TU01	S21-002317	Turmeric powder	Powder
TU02	S21-002318	Turmeric with black pepper	Supplement
TU03	S21-002319	Turmeric tablets	Supplement
TU04	S21-002320	Ground Turmeric	Powder
TU05	S21-002321	Turmeric	Supplement
TU06	S21-002322	Turmeric and black pepper	Supplement
TU07	S21-002323	Organic turmeric	Supplement
TU08	S21-002324	Turmeric	Supplement
TU09	S21-002325	Organic ground Turmeric	Powder
TU010	S21-002326	Turmeric	Powder
TU011	S21-002327	Turmeric powder	Powder
TU012	S21-002328	Curcumin	Supplement
TU013	S21-002329	Turmeric	Supplement
TU014	S21-002330	Turmeric	Powder
TU015	S21-002331	Turmeric	Supplement
TU016	S21-002332	Organic Turmeric powder	Powder
TU017	S21-002333	Turmeric and black pepper	Supplement
TU018	S21-002334	Turmeric and piperine	Supplement
TU019	S21-002335	Turmeric whole	Ordered as fresh but actually whole
TU020	S21-002336	Turmeric and black pepper tablets	Supplement
TU021	S21-002337	Turmeric, ginger and black pepper tablets	Supplement
TU022	S21-002338	Turmeric	Powder
TU023	S21-002339	Ground Turmeric	Powder
TU024	S21-002340	Turmeric powder	Powder
TU025	S21-002341	Cod liver oil and Turmeric	Supplement
TU026	S21-002342	Turmeric	Fresh
TU027	S21-002343	Turmeric	Fresh
TU028	S21-002344	Turmeric	Fresh
TU029	S21-002345	Turmeric	Fresh
TU030	S21-002346	Turmeric with black pepper	Supplement

Table 2: Trace element concentrations

Sample code	TU01	TU02	TU03	TU04	TU05
Sample name	Turmeric powder	Turmeric with black pepper	Turmeric tablets	Ground turmeric	Turmeric
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Lithium	0.116	0.052	0.125	0.12	0.187
Beryllium	0.007	0.005	0.013	0.009	0.014
Boron	4	5	3	5	5
Sodium	271	784	1610	341	977
Magnesium	1960	1770	1130	1990	785
Aluminium	468	384	153	429	541
Silicon	800	800	500	900	1900
Phosphorus	2990	2210	1620	2580	1290
Sulfur	1300	1000	900	1200	900
Potassium	40700	34600	24300	40100	17300

Sample code	TU01	TU02	TU03	TU04	TU05
Calcium	1900	1870	311000	1940	2500
Scandium	0.137	0.139	0.354	0.124	0.153
Titanium	39.9	25.5	281	31.6	9.5
Vanadium	1.79	1.55	0.88	1.44	0.77
Chromium	0.51	0.54	2.39	0.48	1.93
Manganese	42.9	31.4	62.8	62.2	89.9
Iron	317	261	283	259	228
Cobalt	0.294	0.212	0.109	0.21	0.163
Nickel	0.45	0.47	0.33	0.5	1.01
Copper	3.06	2.88	0.4	2.81	1.9
Zinc	9.1	7.1	5.2	9.4	7.4
Gallium	0.12	0.1	0.07	0.11	0.16
Germanium	0.02	0.02	0.04	0.02	0.03
Arsenic	0.035	0.017	0.102	0.036	0.448
Selenium	0.05	0.02	0.04	0.04	0.05
Rubidium	5.92	5.26	21.2	7.81	17.1
Strontium	9.3	11.8	85.8	11.9	17.2
Yttrium	0.174	0.128	0.699	0.139	0.313
Zirconium	0.26	0.2	0.75	0.24	0.23
Niobium	0.026	0.014	0.157	0.022	0.007
Molybdenum	0.11	0.08	0.1	0.15	0.13
Ruthenium	<0.001	<0.001	<0.001	<0.001	<0.001
Rhodium	<0.005	<0.005	<0.005	<0.005	<0.005
Palladium	0.007	0.006	0.047	0.007	0.012
Silver	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	0.013	0.009	0.219	0.037	0.055
Tin	0.01	0.024	0.024	0.011	0.036
Antimony	<0.002	0.003	0.003	0.002	<0.002
Tellurium	<0.01	<0.01	<0.01	<0.01	<0.01
Caesium	0.015	0.011	0.011	0.018	0.031
Barium	5.91	3.92	9.37	8.86	29
Lanthanum	0.123	0.057	0.364	0.177	0.366
Cerium	0.294	0.147	0.299	0.366	0.709
Praseodymium	0.035	0.019	0.057	0.043	0.085
Neodymium	0.156	0.09	0.238	0.177	0.328
Samarium	0.036	0.023	0.047	0.036	0.064
Europium	0.01	0.008	0.012	0.009	0.014
Gadolinium	0.036	0.025	0.057	0.043	0.085
Terbium	0.006	0.004	0.009	0.005	0.01
Dysprosium	0.034	0.026	0.057	0.029	0.057
Holmium	0.007	0.005	0.013	0.005	0.011
Erbium	0.018	0.014	0.04	0.015	0.031
Thulium	0.002	0.002	0.005	0.002	0.004
Ytterbium	0.014	0.011	0.031	0.011	0.025
Lutetium	0.002	0.002	0.005	0.002	0.004
Hafnium	0.009	0.006	0.015	0.007	0.007
Tantalum	0.001	0.001	0.009	0.001	<0.001
Tungsten	0.003	0.008	<0.002	0.004	0.069
Rhenium	<0.001	<0.001	<0.001	<0.001	0.001

Sample code	TU01	TU02	TU03	TU04	TU05
Osmium	<0.005	<0.005	<0.005	<0.005	<0.005
Iridium	<0.001	<0.001	<0.001	<0.001	<0.001
Platinum	<0.001	<0.001	<0.001	<0.001	<0.001
Gold	<0.002	<0.002	<0.002	<0.002	<0.002
Mercury	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	0.009	0.005	0.009	0.009	0.014
Lead	0.071	0.033	0.094	0.116	0.26
Bismuth	<0.001	<0.001	0.004	<0.001	0.003
Thorium	0.036	0.013	0.03	0.058	0.137
Uranium	0.01	0.008	0.166	0.012	0.024

Table 2: Trace element concentrations (continued)

Sample code	TU06	TU07	TU08	TU09	TU10
Sample name	Turmeric and black pepper	Organic turmeric	Turmeric	Organic ground turmeric	Turmeric
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Lithium	0.211	0.203	0.135	0.185	0.247
Beryllium	0.015	0.012	0.007	0.014	0.03
Boron	6	5	4	4	5
Sodium	3010	479	794	398	49
Magnesium	1960	1600	1870	2300	1830
Aluminium	403	1210	514	655	1420
Silicon	700	2000	1700	1000	1600
Phosphorus	134000	3270	2380	2890	2890
Sulfur	1300	1200	1200	1400	1200
Potassium	45200	31900	26300	41300	48000
Calcium	203000	2030	1550	1870	1860
Scandium	0.29	0.25	0.148	0.134	0.198
Titanium	37	24.6	24.3	36.4	30
Vanadium	1.55	1.69	1.32	1.37	1.23
Chromium	0.86	0.36	1.94	1.3	2.11
Manganese	131	333	49.5	28.4	200
Iron	233	408	288	290	357
Cobalt	0.185	0.179	0.235	0.208	0.205
Nickel	0.59	0.32	1.01	0.64	1.34
Copper	0.83	3.12	2.36	2.98	3.15
Zinc	9.4	37.8	9.2	9.4	22
Gallium	0.13	0.22	0.13	0.17	0.32
Germanium	0.03	0.05	0.03	0.04	0.05
Arsenic	0.084	0.095	0.031	0.053	0.133
Selenium	0.06	0.05	0.06	0.06	0.09
Rubidium	32.1	27.7	4.46	9.36	32.8
Strontium	50.7	16.7	13.5	16	18.1
Yttrium	0.758	0.404	0.143	0.193	0.343
Zirconium	1.33	0.32	0.31	0.31	0.18
Niobium	0.06	0.014	0.021	0.046	0.08
Molybdenum	1.87	0.43	0.19	0.16	0.86

Sample code	TU06	TU07	TU08	TU09	TU10
Ruthenium	<0.001	<0.001	<0.001	<0.001	<0.001
Rhodium	<0.005	<0.005	<0.005	<0.005	<0.005
Palladium	0.03	0.012	0.007	0.01	0.012
Silver	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	0.037	0.221	0.017	0.015	0.086
Tin	0.155	0.032	0.012	0.022	0.042
Antimony	0.017	0.005	0.002	0.003	0.01
Tellurium	<0.01	<0.01	<0.01	<0.01	<0.01
Caesium	0.015	0.09	0.011	0.024	0.086
Barium	14.7	49.8	8.37	9.09	33.2
Lanthanum	0.329	0.246	0.196	0.372	0.618
Cerium	0.56	0.455	0.44	0.769	1.19
Praseodymium	0.084	0.062	0.048	0.084	0.134
Neodymium	0.358	0.269	0.189	0.316	0.513
Samarium	0.081	0.061	0.036	0.059	0.095
Europium	0.019	0.022	0.009	0.013	0.022
Gadolinium	0.088	0.067	0.034	0.054	0.086
Terbium	0.015	0.011	0.005	0.008	0.012
Dysprosium	0.093	0.067	0.029	0.04	0.064
Holmium	0.019	0.013	0.006	0.007	0.012
Erbium	0.058	0.04	0.016	0.021	0.033
Thulium	0.008	0.005	0.002	0.003	0.004
Ytterbium	0.049	0.034	0.013	0.016	0.026
Lutetium	0.008	0.005	0.002	0.002	0.004
Hafnium	0.04	0.011	0.01	0.009	0.01
Tantalum	<0.001	<0.001	<0.001	0.003	0.005
Tungsten	0.027	0.018	0.016	0.009	0.039
Rhenium	<0.001	<0.001	<0.001	<0.001	<0.001
Osmium	<0.005	<0.005	<0.005	<0.005	<0.005
Iridium	<0.001	<0.001	<0.001	<0.001	<0.001
Platinum	<0.001	<0.001	<0.001	<0.001	<0.001
Gold	<0.002	<0.002	<0.002	<0.002	<0.002
Mercury	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	0.017	0.104	0.014	0.013	0.041
Lead	0.097	0.288	0.092	0.203	2.25
Bismuth	<0.001	0.002	<0.001	0.001	0.008
Thorium	0.097	0.043	0.061	0.17	0.237
Uranium	0.57	0.012	0.014	0.032	0.037

Table 2: Trace element concentrations (continued)

Sample code	TU11	TU12	TU13	TU14	TU15
Sample name	Turmeric powder	Curcumin	Turmeric	Turmeric	Turmeric
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Lithium	0.132	<0.005	<0.005	0.09	0.32
Beryllium	0.007	0.02	<0.001	0.006	0.016
Boron	5	42	<1	4	5

Sample code	TU11	TU12	TU13	TU14	TU15
Sodium	421	447	78500	285	536
Magnesium	2550	1450	10	1770	1080
Aluminium	587	10.2	<0.5	306	98.1
Silicon	1700	1200	<100	700	400
Phosphorus	3510	20200	<10	2840	82300
Sulfur	1600	<500	<500	1300	<500
Potassium	42200	<20	50	38100	1140
Calcium	2310	28500	46	1570	323000
Scandium	0.202	0.074	<0.005	0.092	0.387
Titanium	58.8	4	<0.1	27.6	12.3
Vanadium	2.61	0.11	0.04	1.19	0.81
Chromium	0.74	0.12	<0.05	0.33	1.17
Manganese	105	1.7	0.2	39.3	31.7
Iron	456	251	<1	193	65
Cobalt	0.439	0.03	<0.005	0.22	0.042
Nickel	0.62	0.08	<0.05	0.41	0.17
Copper	4.46	114	0.05	2.62	0.18
Zinc	21.6	0.4	15.8	8.6	1.7
Gallium	0.16	0.01	<0.01	0.08	0.07
Germanium	0.03	0.02	<0.01	0.02	0.04
Arsenic	0.039	0.01	<0.005	0.034	0.286
Selenium	0.06	<0.01	<0.01	0.05	0.06
Rubidium	5.44	<0.02	0.06	6.78	0.57
Strontium	10.5	13.8	0.37	8.4	76.6
Yttrium	0.213	0.172	<0.001	0.112	4.12
Zirconium	0.32	0.25	<0.01	0.22	0.43
Niobium	0.034	0.01	<0.002	0.02	0.025
Molybdenum	0.11	0.03	<0.02	0.11	0.03
Ruthenium	<0.001	<0.001	<0.001	<0.001	<0.001
Rhodium	<0.005	<0.005	<0.005	<0.005	<0.005
Palladium	0.007	0.009	<0.005	0.015	0.107
Silver	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	0.032	<0.005	<0.005	0.015	0.107
Tin	0.014	0.022	<0.005	0.015	0.107
Antimony	0.004	0.017	<0.002	<0.002	0.24
Tellurium	<0.01	<0.01	<0.01	<0.01	<0.01
Caesium	0.016	<0.001	<0.001	0.015	0.008
Barium	7.05	0.69	0.09	6.13	1.94
Lanthanum	0.144	0.112	<0.001	0.098	1.28
Cerium	0.334	0.149	<0.001	0.216	0.471
Praseodymium	0.043	0.022	<0.001	0.027	0.153
Neodymium	0.188	0.089	<0.001	0.109	0.653
Samarium	0.042	0.017	<0.001	0.024	0.116
Europium	0.012	0.005	<0.001	0.007	0.029
Gadolinium	0.044	0.02	<0.001	0.025	0.177
Terbium	0.007	0.003	<0.001	0.004	0.027
Dysprosium	0.042	0.018	<0.001	0.004	0.027
Holmium	0.008	0.004	<0.001	0.004	0.047
Erbium	0.022	0.012	<0.001	0.002	0.019

Sample code	TU11	TU12	TU13	TU14	TU15
Thulium	0.003	0.002	<0.001	0.002	0.019
Ytterbium	0.019	0.014	<0.001	0.009	0.107
Lutetium	0.003	0.003	<0.001	0.001	0.016
Hafnium	0.011	0.008	<0.001	0.007	0.01
Tantalum	0.002	<0.001	<0.001	0.001	<0.001
Tungsten	0.003	0.031	<0.002	0.003	0.012
Rhenium	<0.001	<0.001	<0.001	<0.001	0.007
Osmium	<0.005	<0.005	<0.005	<0.005	<0.005
Iridium	<0.001	<0.001	<0.001	<0.001	<0.001
Platinum	<0.001	<0.001	<0.001	<0.001	<0.001
Gold	<0.002	<0.002	<0.002	<0.002	<0.002
Mercury	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	0.019	<0.005	<0.005	0.009	<0.005
Lead	0.638	0.023	<0.005	0.231	0.111
Bismuth	<0.001	<0.001	<0.001	<0.001	<0.001
Thorium	0.041	0.01	<0.001	0.031	0.024
Uranium	0.011	0.028	<0.001	0.008	0.237

Table 2: Trace element concentrations (continued)

Sample code	TU16	TU17	TU18	TU19	TU20
Sample name	Organic turmeric powder	Turmeric and black pepper	Turmeric and piperine	Turmeric whole	Turmeric and black pepper tablets
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Lithium	0.243	0.021	0.134	0.106	<0.005
Beryllium	0.014	0.124	0.009	0.006	<0.001
Boron	6	31	4	4	32
Sodium	1030	27	728	148	204
Magnesium	2810	584	1670	1750	375
Aluminium	1220	10.3	363	314	10.5
Silicon	1800	<100	900	500	1300
Phosphorus	3010	58200	2820	3220	30
Sulfur	1600	<500	1300	1200	<500
Potassium	46500	<20	29000	36200	<20
Calcium	3170	83500	1620	1380	16
Scandium	0.426	0.188	0.084	0.093	0.034
Titanium	82.8	4.8	10.8	19.6	0.9
Vanadium	5.95	0.55	0.65	1.11	0.01
Chromium	0.21	0.21	0.52	0.32	0.09
Manganese	48.2	10.1	70	37	0.2
Iron	906	23	154	182	2
Cobalt	0.617	0.015	0.156	0.226	<0.005
Nickel	1.07	<0.05	0.41	0.39	<0.05
Copper	5.38	0.18	2.37	2.44	0.05
Zinc	18.1	0.3	14.7	7.5	<0.2
Gallium	0.31	0.02	0.1	0.08	<0.01
Germanium	0.07	0.02	0.02	0.03	<0.01
Arsenic	0.068	0.015	0.052	0.047	<0.005

Sample code	TU16	TU17	TU18	TU19	TU20
Selenium	0.06	0.03	0.11	0.02	<0.01
Rubidium	7.65	<0.02	13.8	4.91	<0.02
Strontium	14.5	26.9	14.3	7.98	0.09
Yttrium	0.371	1.53	0.168	0.122	0.008
Zirconium	0.34	0.12	0.11	0.16	0.4
Niobium	0.027	0.004	0.021	0.016	0.002
Molybdenum	0.08	0.02	0.12	0.07	0.02
Ruthenium	<0.001	<0.001	<0.001	<0.001	<0.001
Rhodium	<0.005	<0.005	<0.005	<0.005	<0.005
Palladium	0.011	0.038	0.009	0.005	<0.005
Silver	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	0.02	<0.005	0.065	0.014	<0.005
Tin	0.023	0.009	0.026	0.008	<0.005
Antimony	0.003	0.187	0.004	0.002	0.016
Tellurium	<0.01	<0.01	<0.01	<0.01	<0.01
Caesium	0.03	<0.001	0.031	0.02	<0.001
Barium	6.14	0.25	27.7	5.97	0.11
Lanthanum	0.227	0.204	0.23	0.102	0.012
Cerium	0.563	0.396	0.474	0.265	0.029
Praseodymium	0.069	0.066	0.052	0.029	0.003
Neodymium	0.305	0.324	0.203	0.125	0.009
Samarium	0.073	0.104	0.04	0.03	0.002
Europium	0.02	0.024	0.011	0.009	<0.001
Gadolinium	0.075	0.151	0.037	0.032	0.002
Terbium	0.013	0.028	0.005	0.005	<0.001
Dysprosium	0.074	0.185	0.028	0.028	0.001
Holmium	0.014	0.038	0.005	0.005	<0.001
Erbium	0.041	0.109	0.016	0.005	<0.001
Thulium	0.006	0.014	0.002	0.002	<0.001
Ytterbium	0.033	0.082	0.012	0.012	<0.001
Lutetium	0.005	0.012	0.002	0.002	<0.001
Hafnium	0.011	0.003	0.005	0.006	0.01
Tantalum	0.002	<0.001	0.001	0.001	<0.001
Tungsten	0.003	0.035	0.005	0.002	0.003
Rhenium	<0.001	<0.001	<0.001	<0.001	<0.001
Osmium	<0.005	<0.005	<0.005	<0.005	<0.005
Iridium	<0.001	<0.001	<0.001	<0.001	<0.001
Platinum	<0.001	<0.001	<0.001	<0.001	<0.001
Gold	<0.002	<0.002	<0.002	<0.002	<0.002
Mercury	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	0.019	<0.005	0.017	0.007	<0.005
Lead	0.159	0.03	0.152	0.072	0.012
Bismuth	0.002	<0.001	0.001	0.001	<0.001
Thorium	0.066	0.006	0.057	0.032	0.007
Uranium	0.02	0.113	0.017	0.009	0.001

Table 2: Trace element concentrations (continued)

Sample code	TU21	TU22	TU23	TU24	TU25
Sample name	Turmeric, ginger and black pepper tablets	Turmeric	Ground turmeric	Turmeric powder	Cold liver oil and turmeric
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Lithium	<0.005	0.088	0.064	0.175	0.006
Beryllium	<0.001	0.005	0.005	0.01	0.002
Boron	<1	4	5	5	<1
Sodium	52	586	515	332	1340
Magnesium	435	1660	2060	2870	198
Aluminium	2.1	319	436	785	8.7
Silicon	<100	600	1000	1300	1200
Phosphorus	<10	2160	3240	2860	<10
Sulfur	<500	1200	1400	1300	<500
Potassium	<20	31900	39300	42500	<20
Calcium	13	1370	1950	3060	35
Scandium	<0.005	0.089	0.144	0.267	0.03
Titanium	0.2	30.8	30.4	64.1	2.6
Vanadium	<0.01	1.18	1.65	2.97	0.05
Chromium	0.14	1.4	0.36	1.18	0.12
Manganese	<0.1	25.1	30.4	71.2	0.1
Iron	2	198	280	551	4
Cobalt	<0.005	0.196	0.209	0.455	<0.005
Nickel	0.1	0.88	0.39	0.95	<0.05
Copper	<0.05	3	3.23	4.56	0.75
Zinc	0.2	9.5	8.7	11.3	0.6
Gallium	<0.01	0.08	0.12	0.2	<0.01
Germanium	<0.01	0.02	0.03	0.04	<0.01
Arsenic	<0.005	0.093	0.02	0.052	<0.005
Selenium	<0.01	0.04	0.04	0.04	<0.01
Rubidium	<0.02	3.39	5.59	5.55	<0.02
Strontium	0.03	8.51	14.8	13.5	0.15
Yttrium	<0.001	0.095	0.144	0.285	0.016
Zirconium	<0.01	0.23	0.24	0.47	0.28
Niobium	0.004	0.022	0.016	0.039	0.002
Molybdenum	0.16	0.28	0.11	0.1	0.0002
Ruthenium	<0.001	<0.001	<0.001	<0.001	<0.001
Rhodium	<0.005	<0.005	<0.005	<0.005	<0.005
Palladium	<0.005	<0.005	0.009	0.01	<0.005
Silver	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	<0.005	0.013	0.011	0.019	<0.005
Tin	0.02	0.007	0.007	0.018	<0.005
Antimony	<0.002	0.002	<0.002	0.006	<0.002
Tellurium	<0.01	<0.01	<0.01	<0.01	<0.01
Caesium	<0.001	0.01	0.008	0.021	<0.001
Barium	0.04	5.85	7.36	6.39	0.71
Lanthanum	0.001	0.106	0.101	0.159	0.019
Cerium	0.002	0.249	0.244	0.378	0.039
Praseodymium	<0.001	0.03	0.03	0.049	0.005
Neodymium	<0.001	0.12	0.129	0.225	0.016
Samarium	<0.001	0.024	0.03	0.054	0.003

Sample code	TU21	TU22	TU23	TU24	TU25
Europium	<0.001	0.006	0.009	0.016	<0.001
Gadolinium	<0.001	0.027	0.031	0.056	0.003
Terbium	<0.001	0.004	0.005	0.009	<0.001
Dysprosium	<0.001	0.02	0.029	0.055	0.002
Holmium	<0.001	0.005	0.006	0.011	<0.001
Erbium	<0.001	0.011	0.016	0.03	0.002
Thulium	<0.001	0.001	0.002	0.004	<0.001
Ytterbium	<0.001	0.008	0.013	0.024	0.002
Lutetium	<0.001	0.001	0.002	0.003	<0.001
Hafnium	<0.001	0.007	0.009	0.013	0.0004
Tantalum	<0.001	0.002	<0.001	0.002	<0.001
Tungsten	0.035	0.003	0.002	0.003	0.003
Rhenium	<0.001	<0.001	<0.001	<0.001	<0.001
Osmium	<0.005	<0.005	<0.005	<0.005	<0.005
Iridium	<0.001	<0.001	<0.001	<0.001	<0.001
Platinum	<0.001	<0.001	<0.001	<0.001	<0.001
Gold	<0.002	<0.002	<0.002	<0.002	<0.002
Mercury	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	<0.005	<0.005	0.008	0.013	<0.005
Lead	<0.005	0.066	0.05	0.151	0.024
Bismuth	<0.001	<0.001	<0.001	<0.001	<0.001
Thorium	<0.001	03035	0.018	0.043	0.005
Uranium	<0.001	0.013	0.009	0.014	0.004

Table 2: Trace element concentrations (continued)

Sample code	TU26	TU27	TU28	TU29	TU30
Sample name	Turmeric	Turmeric	Turmeric	Turmeric	Turmeric with black pepper
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Lithium	0.01	0.007	0.016	0.007	0.005
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	1	<1	<1	<1	28
Sodium	42	10	20	6	147
Magnesium	411	242	162	243	287
Aluminium	63.6	18.4	28.4	19.7	9.2
Silicon	200	<100	<100	<100	1100
Phosphorus	910	360	210	370	30
Sulfur	<500	<500	<500	<500	<500
Potassium	8850	5740	4460	5750	<20
Calcium	432	236	262	262	21
Scandium	0.024	<0.005	0.007	<0.005	0.028
Titanium	11.1	0.8	1.8	0.8	1.1
Vanadium	0.39	0.02	0.05	0.02	<0.01
Chromium	0.08	<0.05	<0.05	<0.05	<0.05
Manganese	8	1.9	7.9	7.9	<0.1
Iron	49	6	9	6	1

Sample code	TU26	TU27	TU28	TU29	TU30
Cobalt	0.033	0.006	0.007	0.007	<0.005
Nickel	0.08	<0.05	<0.05	<0.05	<0.05
Copper	0.64	0.36	0.17	0.36	0.09
Zinc	2.1	1.9	1.3	1.8	0.2
Gallium	0.02	<0.01	<0.01	<0.01	<0.01
Germanium	<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	<0.005	<0.005	0.007	<0.005	<0.005
Selenium	<0.01	0.03	<0.01	0.02	<0.01
Rubidium	2.01	3.28	0.66	3.52	0.03
Strontium	1.9	0.5	3.42	0.53	0.1
Yttrium	0.024	0.009	0.01	0.01	0.003
Zirconium	0.1	0.02	0.02	0.02	0.18
Niobium	0.007	0.002	0.006	0.004	<0.002
Molybdenum	0.03	0.14	0.15	0.17	<0.02
Ruthenium	<0.001	<0.001	<0.001	<0.001	<0.001
Rhodium	<0.005	<0.005	<0.005	<0.005	<0.005
Palladium	<0.005	<0.005	<0.005	<0.005	<0.005
Silver	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	<0.005	<0.005	0.01	<0.005	<0.005
Tin	0.007	<0.005	0.01	<0.005	<0.005
Antimony	<0.002	<0.002	<0.002	<0.002	0.002
Tellurium	<0.01	<0.01	<0.01	<0.01	<0.01
Caesium	0.002	0.008	0.003	0.006	<0.001
Barium	1.13	1.88	3.98	2.08	0.09
Lanthanum	0.015	0.015	0.018	0.02	0.004
Cerium	0.035	0.028	0.038	0.037	0.008
Praseodymium	0.005	0.003	0.004	0.004	<0.001
Neodymium	0.02	0.014	0.018	0.017	0.003
Samarium	0.005	0.002	0.003	0.003	<0.001
Europium	0.002	<0.001	0.001	<0.001	<0.001
Gadolinium	0.006	0.002	0.003	0.003	<0.001
Terbium	<0.001	<0.001	<0.001	<0.001	<0.001
Dysprosium	0.005	0.002	0.002	0.002	<0.001
Holmium	0.001	<0.001	<0.001	<0.001	<0.001
Erbium	0.003	<0.001	0.001	0.001	0.001
Thulium	<0.001	<0.001	<0.001	<0.001	<0.001
Ytterbium	0.002	<0.001	<0.001	<0.001	<0.001
Lutetium	<0.001	<0.001	<0.001	<0.001	<0.001
Hafnium	0.004	<0.001	<0.001	<0.001	0.0004
Tantalum	<0.001	<0.001	<0.001	<0.001	<0.001
Tungsten	<0.002	0.005	<0.002	0.002	<0.002
Rhenium	<0.001	<0.001	<0.001	<0.001	<0.001
Osmium	<0.005	<0.005	<0.005	<0.005	<0.005
Iridium	<0.001	<0.001	<0.001	<0.001	<0.001
Platinum	<0.001	<0.001	<0.001	<0.001	<0.001
Gold	<0.002	<0.002	<0.002	<0.002	<0.002
Mercury	<0.005	<0.005	<0.005	<0.005	<0.005
Thallium	<0.005	<0.005	<0.005	<0.005	<0.005
Lead	0.011	0.018	0.018	0.018	0.008

Sample code	TU26	TU27	TU28	TU29	TU30
Bismuth	<0.001	<0.001	<0.001	<0.001	<0.001
Thorium	0.003	0.006	0.005	0.006	0.003
Uranium	0.002	<0.001	0.003	0.001	0.002

Table 3: Curcuminoid concentrations

Sample code	Product	Average mass per tablet/capsule (g)	Curcumin Concentration (mg/kg): A	Curcumin Concentration (mg/kg): B	DMC Concentration (mg/kg): A	DMC Concentration (mg/kg): B	BDMC Concentration (mg/kg): A	BDMC Concentration (mg/kg): A	Total Curcuminoids Concentration (mg/kg): A	Total Curcuminoids Concentration (mg/kg): B
TU01	Turmeric powder	NA	11,734	15,244	5,610	6,797	4,181	5,920	21,525	27,960
TU02	Turmeric with black pepper	0.60	9,027	10,139	3,806	4,131	3,055	3,500	15,888	17,770
TU03	Turmeric tablets	0.42	14,033	14,094	2,792	3,153	<LOQ	<LOQ	16,825	17,247
TU04	Ground Turmeric	NA	7,401	7,220	2,911	2,613	2,384	2,252	12,697	12,084
TU05	Turmeric	0.62	98,476	101,898	29,088	31,088	8,905	9,251	136,469	142,237
TU06	Turmeric and black pepper	0.35	24,630	22,962	4,804	5,092	<LOQ	<LOQ	29,434	28,054
TU07	Organic Turmeric	0.46	22,085	25,256	9,826	11,153	8,503	9,953	40,415	46,362
TU08	Turmeric	0.53	80,671	81,022	23,871	24,744	8,309	8,472	112,850	114,238
TU09	Organic turmeric powder	NA	14,154	13,688	6,066	5,790	4,126	4,120	24,346	23,598
TU010	Turmeric	NA	19,430	20,852	8,981	11,245	8,159	9,693	36,570	41,790
TU011	Turmeric powder	NA	13,060	14,870	6,261	6,929	5,135	5,798	24,455	27,598
TU12	Curcumin	1.00	438,679	466,572	31,578	34,215	5,590	6,566	475,847	507,309
TU13	Turmeric	3.96	35,686	38,380	9,732	7,759	2,275	2,365	47,875	48,504
TU14	Turmeric	NA	13,777	15,542	6,544	8,524	4,783	6,501	25,104	30,567
TU15	Turmeric	1.57	69,805	66,148	20,086	16,064	4,781	4,356	94,672	86,568
TU16	Organic Turmeric powder	NA	9,991	22,962	4,548	5,092	4,932	<LOQ	19,471	28,054
TU17	Turmeric and black pepper	0.15	286,110	258,679	13,279	12,958	3,324	3,014	302,712	274,651
TU18	Turmeric and piperine	0.61	11,670	11,075	4,625	4,195	4,556	4,660	20,851	19,930
TU19	Turmeric whole	NA	17,717	16,420	9,182	8,598	6,517	6,312	33,416	31,330
TU20	Turmeric and black pepper tablets	0.25	58,081	59,475	<LOQ	<LOQ	<LOQ	<LOQ	58,801	59,745
TU21	Turmeric, ginger and black pepper tablets	0.34	25,735	24,505	6,870	6,967	3,519	3,284	36,124	34,756
TU22	Turmeric	NA	7,196	7,201	2,424	2,738	2,504	2,589	12,125	12,528
TU23	Ground turmeric	NA	16,554	15,931	6,925	6,483	5,925	5,554	29,404	27,967
TU24	Turmeric powder	NA	13,688	14,050	5,558	5,880	4,978	5,069	24,224	24,998
TU25	Cod liver oil and turmeric	0.72	78,678	88,601	24,446	29,199	11,862	12,253	114,986	130,324

Samplecode	Product	Average mass per tablet/capsule (g)	Curcumin Concentration (mg/kg): A	Curcumin Concentration (mg/kg): B	DMC Concentration (mg/kg): A	DMC Concentration (mg/kg): B	BDMC Concentration (mg/kg): A	BDMC Concentration (mg/kg): A	Total Curcuminoids Concentration (mg/kg): A	Total Curcuminoids Concentration (mg/kg): B
TU26	Turmeric (dry weight basis)	NA	24,271	23,195	11,530	10,165	9,353	9,361	45,155	42,270
TU26	Turmeric	NA	4,662	4,455	2,215	1,952	1,796	1,798	8,673	8,205
TU27	Turmeric	NA	16,278	18,492	11,112	12,614	5,819	7,130	33,209	38,237
TU27	Turmeric (dry weight basis)	NA	2,059	2,339	1,405	1,595	736	902	4,200	4,835
TU28	Turmeric (dry weight basis)	NA	36,591	49,527	19,796	27,391	18,008	25,817	74,395	102,735
TU28	Turmeric	NA	2,749	3,721	1,487	2,058	1,353	1,940	5,589	7,718
TU29	Turmeric (dry weight basis)	NA	15,352	15,228	10,255	10,718	5,606	5,817	31,213	31,763
TU29	Turmeric	NA	1,993	1,977	1,332	1,392	728	755	4,053	4,124
TU30	Turmeric with black pepper	0.25	46,584	44,378	<LOQ	<LOQ	<LOQ	<LOQ	46,584	44,378
Control	Ground Ginger	NA	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ

Table 4: Piperine concentrations

Sample number	Product	Average mass per tablet/capsule (grams)	Piperine Concentration (mg/kg): A	Piperine Concentration (mg/kg): B
TU02	Turmeric with black pepper	0.60	1,170	1,130
TU03	Turmeric tablets	0.42	<LOQ	<LOQ
TU05	Turmeric	0.62	3,277	4,022
TU06	Turmeric with black pepper	0.35	92,131	89,469
TU07	Organic Turmeric	0.46	<LOQ	<LOQ
TU08	Turmeric	0.53	<LOQ	<LOQ
TU12	Curcumin	1.00	16,776	19,558
TU13	Turmeric	3.96	<LOQ	<LOQ
TU15	Turmeric	1.57	7,837	7,270
TU17	Turmeric with black pepper herbal extract	0.15	164,103	199,609
TU18	Turmeric and piperine	0.61	653	457
TU20	Turmeric with black pepper tablets	0.25	31,629	38,423
TU21	Turmeric, ginger and black pepper tablets	0.34	34,457	33,129
TU25	Cod liver oil and Turmeric	0.34	<LOQ	<LOQ
TU30	Turmeric with black pepper	0.34	140,509	138,428
Control	Ground ginger	Not applicable	<LOQ	<LOQ

Limit of quantification: Piperine = 107 mg/kg.