Heavy metals and cannabis

The challenges of measuring heavy metals in cannabis and cannabis-infused products.

THE LACK OF federal oversight with regard to measuring contaminants in cannabis and cannabis-infused food products made in the US has meant that it has been left to the individual states to regulate the use of cannabis.

Marijuana (both medical and recreational) is legal in 33 states and the District of Columbia (Washington, DC).[1] However, the cannabis and hemp plants are known to be hyperaccumulators of contaminants such as heavy metals in the growing medium, soil, fertiliser and nutrients, so it is critical to monitor levels of elemental contaminants to ensure that cannabis and its food-based products are safe to consume.[2]

State-based regulations

The majority of states in the US require manufacturers of these products to show compliance by measuring four major heavy metals: lead (Pb), arsenic (As), cadmium (Cd) and mercury (Hg). All must be below maximum limits, based mainly on regulations set by the pharmaceutical industry in USP Chapter 232 and ICH Q3D guidelines.[3,4] California, which is considered to be the gold standard in regulating cannabis and hemp, dictates that oral (edibles) and inhaled (vapes) cannabis products are safe to consume only if these four heavy metals are present a levels below those shown in **Table 1**, based on typical consumption of 10g/day.[5]

At these extremely low contaminant levels, it is critically important that the optimum sampling, sample preparation and testing procedures are implemented, so the test results of the samples being analysed are not only accurate, but also indicative of the cannabis and cannabis products being tested. »

Bob Lockerman

Bob graduated from the University of New Hampshire with a Bachelor of Science degree in analytical chemistry. Upon graduation, he worked as a bench chemist for a commercial testing lab in Massachusetts. He was also part of the team that developed the world's first microwave digestion system.

Table 1

Heavy metal limits in Cannabis and hemp required by the state of California[5]

Element	Maximum Limit (Edibles) µg/g	Maximum Limit (Inhaled Products) µg/g
Pb	0.5	0.5
As	1.5	0.2
Cd	0.5	0.2
Hg	3.0	0.1

Table 2

The Microwave digestion conditions used in this study

Variable	Value
Sample Matrix	All 11 Matrices
Sample Weight	0.5g
Acid Mixture	9:1 HNO_3:HCl
Acid Volume	10ml
Sample Rack Capacity	24 Samples
Ramp Time	20min
Hold Time/Temperature	15min at 210°C
Cool-down Time	10min
Total Digestion Time	45min

Analytical procedures

The state of California requires that at least half a gram of sample is taken for testing purposes and recommends that inductively coupled plasma mass spectrometry (ICP-MS) is used to carry out the measurements. ICP-MS is a sophisticated multielement analytical technique, capable of measuring down to parts per trillion (ppt) levels using mass spectrometry to identify and measure positively charged ions, which are generated in an extremely energetic argon plasma at approximately 6,000-7,000°C.[6] However, this method is predominantly a solution technique, which means that any solid samples must be dissolved/digested before being presented to the instrument. Most cannabis-related samples are solid materials, powders, concentrates and extracts, which invites several challenges. In addition, cannabinoid oils, which are mainly hydrophobic (not miscible with water), must also be digested prior to analysis.

Microwave digestion

The most common means of dissolving cannabis samples is using microwave digestion in combination with concentrated mineral acids such as nitric acid, hydrochloric acid and/or hydrogen peroxide. Microwave technology offers clear benefits over traditional hot block digestion, owing to the higher temperatures achieved in the closed vessel. Typical microwave digesting temperatures are in excess of 200°C compared to the boiling point of a concentrated mineral acid mixture of around 120°C in a convention hot block system.

Although the oxidation reaction is efficient at 200°C, microwave digestion techniques tend to generate large amounts of gases such as carbon dioxide (CO_2) and nitrogen dioxide (NO_2) when they react with plant-type samples such as cannabis and its many associated products. The microwave system and its components must therefore not only accommodate the high temperature required to digest all the different organic components in the samples, but also be able to handle the subsequent increase in pressure produced by the generation of large volumes of these gases. Unfortunately, the higher the sample weight taken, the more gases generated.

Cannabis testing labs

Cannabis testing labs are tasked with characterising an array of different sample types – from flowers and oils to tinctures and edibles – and it can be challenging to prepare these samples simply and economically.

The traditional problem associated with microwave digestion systems was that the numerous samples encountered by a cannabis testing lab had to be segregated by type in order »

Figure 1

The range of cannabis-related samples studied

Jon Peters

Jon has fifteen years of experience with marketing and analytical instrumentation and has worked extensively with ICP, ICPMS, AA, TOC and X-Ray analytical instrumentation.

Table 3

Concentrations (ppb) of As, Cd, Hg and Pb in the digestion blank, hard candy, granola bar, lotion, gummy bear and hemp flower, together with % spike recoveries of 5 ppb

		^{75}As	^{111}Cd	^{200}Hg	^{208}Pb			^{75}As	^{111}Cd	^{200}Hg	^{208}Pb
Blank	Mean value	n.d.	n.d.	n.d.	n.d.	Lotion	Mean value	n.d.	n.d.	n.d.	n.d.
	RSD (n = 3)	–	–	–	–		RSD (n = 3)	–	–	–	–
Spiked Blank	Mean value	5.23	5.23	5.1	5.08	Spiked Lotion	Mean value	4.96	5.09	5.16	5.03
	RSD (n = 3)	2.03	0.76	3.57	1.59		RSD (n = 3)	11.08	1.21	3.12	2.62
Recovery (%)		105	105	102	102	Recovery (%)		99	102	103	101
Hard Candy	Mean value	n.d.	n.d.	n.d.	0.0116	Gummy Bear	Mean value	n.d.	n.d.	n.d.	0.0407
	RSD (n = 3)	–	–	–	1.79		RSD (n = 3)	–	–	–	0.66
Spiked Hard Candy	Mean value	5.12	4.92	5.05	5.13	Spiked Gummy Bear	Mean value	4.76	4.9	4.83	5.07
	RSD (n = 3)	3.51	1.68	0.19	1.74		RSD (n = 3)	0.95	0.74	1.46	1.92
Recovery (%)		102	98	101	102	Recovery (%)		95	98	97	101
Granola Bar	Mean value	n.d.	0.125	n.d.	0.0186	Hemp Flower	Mean value	0.0231	n.d.	n.d.	0.163
	RSD (n = 3)	–	1.63	–	3.02		RSD (n = 3)	6.07	–	–	1.09
Spiked Granola Bar	Mean value	4.55	5.07	5.09	5.06	Fortified Hemp Flower	Mean value	4.81	5.05	5.11	5.15
	RSD (n = 3)	13.53	1.61	1.58	1.15		RSD (n = 3)	9.68	1.22	0.6	1.48
Recovery (%)		91	99	102	101	Recovery (%)		96	101	102	100

n.d = not detected

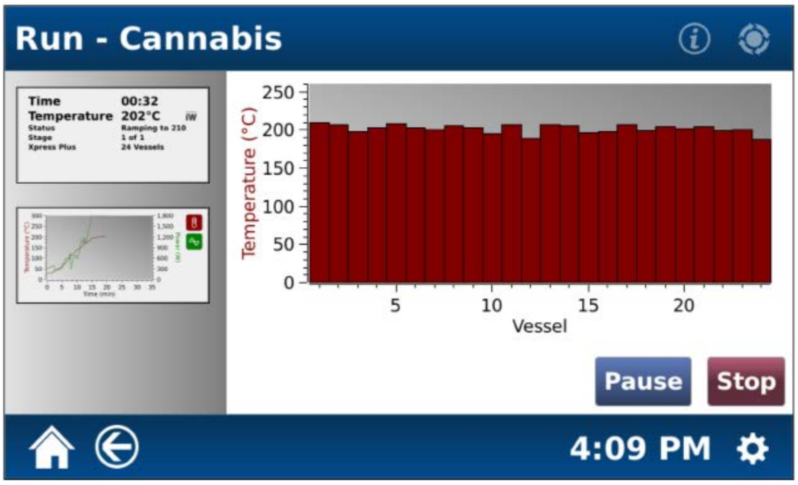
Table 4

Concentrations (ppb) of As, Cd, Hg and Pb in the MCT oil, ghee, hemp oil, beef jerky, peanut butter and CBD oil, together with % spike recoveries of 5 ppb

		^{75}As	^{111}Cd	^{200}Hg	^{208}Pb			^{75}As	^{111}Cd	^{200}Hg	^{208}Pb
MCT oil	Mean value	n.d.	n.d.	n.d.	n.d.	Beef Jerky	Mean value	n.d.	0.0482	n.d.	0.057
	RSD (n = 3)	–	–	–	–		RSD (n = 3)	–	0.77	–	1.65
Spiked MCT Oil	Mean value	5.39	5.04	5.13	4.94	Spiked Beef Jerky	Mean value	4.81	5.07	5.06	5.22
	RSD (n = 3)	1.36	1.54	1.24	1.89		RSD (n = 3)	7.54	1.17	1.25	1.86
Recovery (%)		108	101	103	99	Recovery (%)		96	100	101	103
Ghee	Mean value	n.d.	n.d.	n.d.	n.d.	Peanut Butter	Mean value	n.d.	0.111	n.d.	0.0511
	RSD (n = 3)	–	–	–	–		RSD (n = 3)	–	3.92	–	1.32
Spiked Ghee	Mean value	5.46	5.05	5.15	5	Spiked Peanut Butter	Mean value	5.22	5.28	5.13	5.11
	RSD (n = 3)	3.8	2.01	1.19	1.73		RSD (n = 3)	5.32	1.08	1.45	2.93
Recovery (%)		109	101	103	100	Recovery (%)		104	103	103	101
Hemp Oil	Mean value	n.d.	n.d.	n.d.	0.0723	Conc. CBD Oil	Mean value	n.d.	n.d.	n.d.	0.0662
	RSD (n = 3)	–	–	–	1.6		RSD (n = 3)	–	–	–	0.78
Spiked Hemp Oil	Mean value	5.27	5.18	5.2	5.09	Spiked Conc. CBD Oil	Mean value	5.41	5.17	4.93	5.05
	RSD (n = 3)	11.91	1.53	2.1	1.5		RSD (n = 3)	10.43	0.7	2.03	2.74
Recovery (%)		105	104	104	100	Recovery (%)		108	103	99	100

n.d = not detected

Figure 2



Microwave heating programme, showing that all 24 samples have achieved the same temperature in the same batch

to run in the microwave. The range of matrices presented often made this a difficult task because some samples would be completely dissolved while others were only partially digested. For that reason, samples with similar matrices had to be batched together, which necessitated running multiple sample types, one matrix at a time.

However, recent developments with vessel design, sensor technology, temperature measurement and control, as well as improved software algorithms has meant that power levels can now be optimised, enabling individual sample vessels in the same batch to reach a similar temperature. This means that different matrices can be mixed in a single batch to achieve an efficient and complete digestion of all sample types.

To demonstrate the capabilities of this microwave technology (MARS 6, CEM Corp, Matthews, NC), eleven different cannabis-related samples were digested including hemp flower, hemp oil, MCT (medium chain triglyceride) oil, topical cream, crude CBD oil, beef jerky, peanut butter, ghee (butter), granola bar, gummy snacks and hard candy. **Figure 1** shows the range of samples investigated.

The microwave digestion conditions are presented in **Table 2**, while a screenshot of the heating programme, showing the similar temperatures achieved by all 24 samples, can be seen in **Figure 2**.

Analytical procedure

To exemplify the efficiency of digestion, five ppb of Pb, As, Cd and Hg were spiked into each vessel, prior to digestion. The resulting solutions after digestion were made up to a volume of 50ml. The solution is further diluted to bring the total acid concentration to five percent before being analysed by ICP-MS (Model 2030, Shimadzu, Corp, Columbia, MD) using the Niagara rapid rinse autosampler system (Glass Expansion, Pocasset, MA) to optimise sample delivery and washout to improve sample throughput by a factor of two.

For lotions, creams and hemp flower that might contain silica (SiO_2) or titanium dioxide (TiO_2), it is normal to add several drops of hydrofluoric acid to aid the digestion. However, for safety reasons it was not used in this study, so those samples were filtered prior to making up to volume.

Results

The results for the spike recovery study are shown in **Tables 3 and 4**. Concentrations of elements are in ppb in the digested solutions of the original samples, together with the percentage spike recoveries of five ppb.

Recovery was calculated by subtracting measured concentrations from spiked concentrations. It can be seen that the majority of the analytes were not detected, while spike recoveries and relative standard deviation (RSD) of three replicates of five ppb spikes are all well within the validation protocols specified in the United States Pharmacopeia (USP) Compendial Chapter <233> of 70-150 percent recovery of the spike with an RSD of less than 15 percent.[7]

This investigation has shown that different types of cannabis and cannabis-infused products can be dissolved very efficiently in the same microwave digestion method without the need to batch similar sample types. In approximately one hour, a rack of 24 samples can be digested, cooled, made up to volume and presented to the ICP-MS instrument for analysis. In addition, by using an optimised sampling procedure, the sample throughput can be improved by a factor of two compared to using a conventional autosampler.

Robert Thomas

Robert is the principal of Scientific Solutions, a consulting company that serves the training, application, marketing and writing needs of the trace ele¬ment user community. He has worked in the field of atomic and mass spectroscopy for more than 45 years, including 25 years for a manufacturer of atomic spectroscopic instrumentation. He has also served on the American Chemical Society (ACS) Committee on Analytical Reagents (CAR) for the past 19 years as leader of the plasma spectrochemistry, heavy metals task force, where he has worked very closely with the United States Pharmacopeia (USP) to align ACS heavy metal testing procedures with pharmaceutical guidelines. Robert has an advanced degree in analytical chemistry from the University of Wales, UK and is also a Fellow of the Royal Society of Chemistry (FRSC) and a Chartered Chemist (CChem).

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