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Elemental Analysis of Animal Feed and Fertilizers Produced From Insects

Supporting safe regenerative farming practices using the Agilent 5800 VDV ICP-OES

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Introduction

An increasing trend involves the use of insects for processing food and organic waste. This practice not only reduces the volume of waste that goes to landfill but also lowers methane emissions at waste disposal sites, while preserving essential nutrients within the food chain. Using purpose-designed waste management units, insects such as Black Soldier Fly (BSF) larvae can convert food waste into a valuable source of protein for use in animal feed in less than two weeks.[1]

The composition of the substrate (material used to rear the insects) affects the growth, development, and chemical composition of both the BSF larvae and the by-product of insect farming, which is known as "frass."[2] Since frass contains a high concentration of the primary macronutrients, nitrogen (N), potassium (K), and phosphorus (P), it is increasingly used as an organic fertilizer to improve plant growth and absorption of nutrients by crops. Producing fertilizer from insects is more sustainable than using conventional industrial fertilizer-production practices, as insect-farming requires less water and generates lower greenhouse gas emissions.

Determining the elemental composition of organic waste, larvae, and insect-protein ingredients informs research, development, and production of insect-derived protein, as well as ensuring the safety and quality of the final product. It is also important to determine the concentration of macronutrients and contaminants in frass and frass-derived fertilizers in accordance with regulations for organic fertilizing products to ensure they contribute positively to soil quality without causing harm. Metals such as arsenic (As) and cadmium (Cd) could pose a safety risk to humans or animals as they accumulate in the environment and can enter the food-chain via the consumption of plants or crops.

Agilent Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) instruments are well suited for the analysis of multiple elements in various sample types, including animal feed and fertilizer.[3, 4] ICP-OES allows for simultaneous and rapid determination of a wide range of elements, making it a powerful technique for multi-element analysis of insect-derived samples. The speed, sensitivity, and stability capabilities of the technique are useful for quality control (QC) of animal feed and fertilizers, where the accurate measurement of essential and contaminant elements is important for labeling and product safety purposes.

In this study, an Agilent 5800 Vertical Dual View (VDV) ICP-OES was used to measure 26 elements in organic waste, BSF larvae, insect meal, unprocessed frass, and frass pellets. The 5800 and Agilent ICP Expert Pro software includes several smart tools to ensure a robust and reliable method for the analysis of the different sample-types.[5] The following tools were used in this method to simplify method development and analysis, while ensuring the accuracy of the results and performance of the instrument:

IntelliQuant Screening: an ideal tool for method development. The simple-to-use software function performs a full semiquantitative spectrum scan of up to 78 elements in just a few seconds.[6] The data informs the best calibration range to use for different elements, identifies potential interferences, and helps the analyst choose the best wavelength for the quantitative method.

Intelligent Rinse: a software routine that automatically optimizes the rinse time between samples to prevent carryover, ensuring the accuracy of the results.[7] The software applies the optimum rinse time by monitoring the intensities of nominated element wavelengths until they reach a user-specified threshold. Intelligent Rinse increases sample throughput while maintaining result accuracy.

Fitted Background Correction (FBC): a default function that provides automatic correction of simple and complex background structures.[8] FBC makes it easier than ever to correct background peaks without requiring extensive knowledge—or prior investigation—of the sample matrix.

Experimental

Instrumentation

The Agilent 5800 VDV ICP-OES was fitted with the standard sample introduction system, which consists of a SeaSpray concentric nebulizer, double-pass glass cyclonic spray chamber, and an Easy-fit semi-demountable torch with a 1.8 mm injector. Samples were introduced to the 5800 using an Agilent SPS 4 autosampler.

To provide the robustness and stability of the plasma over long analytical runs of varied matrix samples, the 5800 uses a vertical torch, solid-state radio frequency (SSRF) generator operating at 27 MHz, a high-speed Vista Chip III CCD detector, and a Cooled Cone Interface (CCI). The Vista Chip III detector provides high-speed continuous wavelength coverage, allowing the analyst to choose multiple wavelengths for each element without adding a time delay to the analysis. As different wavelengths often have different sensitivities, a combination of wavelengths can be used for the same element. In this study, the MultiCal function within the ICP Expert software was used to create multiple calibration ranges for magnesium (Mg) and calcium (Ca)—a quick and effective way to extend the Linear Dynamic Range (LDR) without any trade-off in performance.

The instrument operating conditions were optimized to take account of easily ionizable elements (EIEs), such as sodium (Na), potassium (K), Mg, and Ca, which have low ionization energies and are easily ionized in the plasma. If EIEs are present in a sample at a high enough concentration, the plasma electron density and the atomization-ionization equilibria are affected. These effects cause either an enhancement or suppression of the emission signals, leading to the reporting of either false high or false low element concentrations. Na, K, Mg, and Ca are typically present at high concentrations in insect-derived samples, so yttrium (Y) was used as an internal standard at a concentration of 5 ppm to correct for EIE interferences. The internal standard was added in-line.

To account for differing sample matrices and elemental concentrations, the Intelligent Rinse function within the software was used to prevent carryover between samples by automatically optimizing the rinse time between samples. Instrument and method conditions are given in Table 1.

Table 1. Agilent 5800 VDV ICP-OES instrument and method conditions.

Parameter	Setting	
Viewing Mode	Axial	Radial
Read Time (s)	10	10
Replicates	3	
Sample Uptake Delay (s)	20	
Stabilization Time (s)	10	0
Intelligent Rinse	Enabled	
Pump Speed (rpm)	12	
RF Power (kW)	1.4	
Aux Flow (L/min)	1	
Plasma Flow (L/min)	12	
Nebulizer Flow (L/min)	0.7	
Viewing Height (mm)	NA	8
Sample Pump Tubing	White-white	
Waste Pump Tubing	Blue-blue	
Internal Standard Pump Tubing	Orange-green	
Internal Standard	Yttrium (5 ppm)	
Background Correction	Fitted (FBC)	
Maximum Rinse Time (s)	60	

Intelligent Rinse

The concentration of major and trace elements present in the samples was expected to vary, so the Intelligent Rinse software function was used to optimize the rinse times. Intelligent Rinse operates by setting a baseline from the blank and sets a maximum standard deviation (SD) boundary based on the parameter chosen for each wavelength.

There are three defined washout thresholds within Intelligent Rinse: quick, moderate, and thorough. Monitoring signal intensities means that rinse periods vary, depending on the rinse required for each sample. 'Thorough' is typically used for samples with high concentrations of major elements, such as Ca and Mg, or samples that contain "sticky" elements, such as B, Mo, or Se that do not wash out easily.

In this study, Intelligent Rinse ensured fast sample-to-sample times, especially for solutions with lower concentrations of Ca and Mg. As a result of optimizing rinse times for each sample, Intelligent Rinse also optimized argon, electricity, and water usage, lowering the overall operational costs of the analysis.

Method development using IntelliQuant Screening

IntelliQuant Screening was used to obtain quick scan data of the elemental composition of the samples, informing the preparation of the calibration standards over suitable calibration ranges. IntelliQuant Screening identified high concentrations of Ca, K, Mg, and Na in all sample types and relatively low concentrations of most other elements within the matrices. The data informed the decision to produce two different calibration sets for the 'major' and 'trace' elements, each covering different concentration ranges. This approach significantly streamlined the method development process.

The data also provided insights into spectral interferences and recommended the best wavelengths to use for the quantitative analysis of the samples.

Figure 1 shows how IntelliQuant Screening can be used to select an interference free line for boron (B) before any samples are analyzed, avoiding the need for interference correction. The software automatically ranks the B 249.678 wavelength above B 249.772 based on a likely iron (Fe) interference at 249.771 nm, as explained in the dialog box.
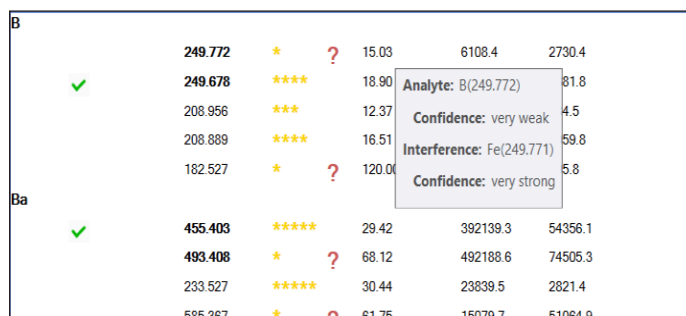

Figure 1. IntelliQuant Screening star ratings and suggested (green tick) wavelengths for boron and barium. Hovering the cursor over the red question provides information for the low star rating. The dialog box for B 249.772 nm suggests a likely interference from Fe 249.771 nm.

Samples and reference materials

Samples, including organic waste, BSF larvae, insect meal, unprocessed frass, and frass pellets, were obtained from a supplier of insect products in Melbourne, Australia. National Institute of Standards and Technology (NIST) 1566b Oyster Tissue standard reference material (SRM, Gaithersburg, US) was used to evaluate the recoveries of elements following the sample digestion procedure.

Sample preparation

The sample-types ranged from powdered insect meal, dehydrated BSF larvae, pelletized frass, and sludge-like organic waste. The powdered samples and organic waste were prepared as received, and the BSF larvae and frass were crushed and homogenized using a pestle and mortar before microwave digestion. Multiple aliquots of the samples were taken from different sections of the bag or container to ensure sample homogeneity.

Approximately 0.5 g of each sample was accurately weighed using an analytical balance and transferred into BLADE quartz vessels (CEM, Buckingham, UK). 8 mL of HNO_3 and 1 mL of H_2O_2 were then added to each sample vessel. If an immediate reaction was observed, the vessels were left uncapped in the fume-hood for approximately 15 to 20 minutes. After this time, the samples were capped, placed into the BLADE microwave digestion system (CEM), digested at 250 °C and held at temperature for 25 minutes, as described in Table 2. After digestion and cooling, the solutions were transferred to 50 mL polypropylene microcentrifuge tubes and diluted to 50 mL with 18.2 MΩ de-ionized (DI) water (Merck Millipore).

As the 1566b Oyster Tissue SRM contains a relatively high amount of aluminosilicates, a high temperature setting was used to prevent a low bias measurement of aluminum (Al).

Table 2. Microwave digestion parameters.

Parameter	Setting
Power (W)	Variable – adjusted by microwave
Ramp Time (min)	15
Hold Time (min)	25
Control Temperature (°C)	250

Spiked samples

An unprocessed frass sample was spiked post-digestion using Agilent Single Element Standards to known final concentrations, as detailed in Table 6.

Calibration standards

All the calibration standards were prepared using Agilent 10,000 ppm single element stock standards. Traditionally, quantification of major and trace elements by ICP-OES required thoughtful preparation of separate calibration ranges.

However, based on the semiquantitative data generated by IntelliQuant Screening, the calibration range was tailored for each element, as shown in Table 3. The standards were diluted with HNO_3 and DI water to a final concentration of 16% HNO_3.

QC solutions

The Continuing Calibration Blank (CCB) and Continuing Calibration Verification (CCV) solutions were used to test the accuracy of the calibration, and to check for potential contaminants in the reagents used to prepare the calibration standards. The CCV was analyzed after every 10 samples to ensure the ongoing validity of the calibration.

Automatic background correction

The analysis of complex samples such as frass pellets and organic waste can be hindered by spectral interferences. These background structures can be automatically corrected by modeling the background to each analyte peak using fitted background correction (FBC).

The FBC algorithm automatically removed the two most prominent interferent background peaks on either side of the B 249.678 nm analyte peak. Figure 2 shows the automated background correction accounting for the Fe 249.653 emission line on the left, as well as the Mn 249.688 and Fe 249.699 lines on the right.
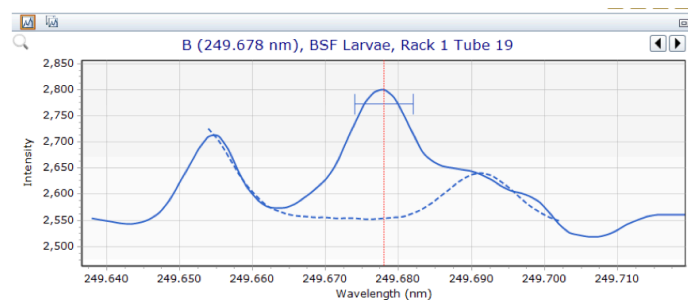

Figure 2. An example of automated background correction of B 249.678 nm using FBC.

Calibration

Linear calibrations were obtained for all 26 elements analyzed using the 5800, as indicated by the calibration coefficients reported in Table 3. All calibrations maintained a minimum calibration coefficient equal to or greater than 0.9996.

Table 3. Wavelengths, background correction, internal standards, and calibration range for each element.

Element and Wavelength (nm)	Background Correction	Calibration Range (mg/L)	Correlation Coefficient	Viewing Mode
Al 396.152	Fitted	0.01 − 20	0.99900	Axial
As 188.980	Fitted	0.01 − 10	1.00000	Axial
B 249.678	Fitted	0.01 − 10	1.00000	Axial
Ba 455.403	Fitted	0.01 − 10	0.99999	Axial
Ca*	Fitted	1 − 500	0.99964	Radial
Cd 214.439	Fitted	0.01 − 10	1.00000	Axial
Co 238.892	Fitted	0.01 − 10	1.00000	Axial
Cr 267.716	Fitted	0.01 − 10	1.00000	Axial
Cu 327.395	Fitted	0.01 − 10	1.00000	Axial
Fe 238.204	Fitted	0.01 − 20	0.99999	Axial
K 766.491	Fitted	1 − 100	1.00000	Radial
Mg*	Fitted	1 − 200	0.99980	Radial
Mn 257.610	Fitted	0.01 − 10	1.00000	Axial
Mo 202.032	Fitted	0.01 − 10	1.00000	Axial
Na 589.592	Fitted	1 − 100	0.99985	Radial
Ni 231.604	Fitted	0.01 − 10	1.00000	Axial
P 213.618	Fitted	1 − 1000	0.99992	Radial
Pb 220.353	Fitted	0.01 − 10	1.00000	Axial
S 181.972	Fitted	1 − 1000	0.99995	Radial
Se 196.026	Fitted	0.01 − 10	1.00000	Axial
Si 251.611	Fitted	1 − 20	0.99962	Axial
Sr 421.552	Fitted	0.1 − 10	0.99999	Axial
Ti 334.941	Fitted	0.01 − 10	1.00000	Axial
Tl 190.794	Fitted	0.01 − 10	1.00000	Axial
V 292.401	Fitted	0.01 − 10	1.00000	Axial
Zn 213.857	Fitted	0.01 − 20	0.99999	Axial

*MultiCal was used for the measurement of Ca and Mg, as the intensity of emissions of Ca and Mg varies depending on wavelength, affecting the LDR of the elements.

Results and discussion

Analytical limits

Limits of detection (LODs) and limits of quantification (LOQs) are important indicators of the performance of an analytical method. The LOQ indicates the lowest concentration of the element that can be accurately and repeatedly quantified within an acceptable degree of tolerance.

The LOD and LOQ for each element were established using 3 and 10 times the standard deviation (sigma) of 10 repeated measurements of 10 blank sample matrix solutions, respectively. The values presented in Table 4 are the average of three sets of LOD and LOQ results measured on three non-consecutive days, calculated in solution. The LODs and LOQs for the major elements, P, and sulfur (S) were determined radially.

Table 4. Agilent 5800 VDV ICP-OES analytical limits based on sample preparation (0.50 g sample in 50 mL final volume).

Element and Wavelength (nm)	LOD (mg/kg)	LOQ (mg/kg)
Al 396.152	0.13	0.42
As 188.980	0.21	0.70
B 249.678	0.17	0.58
Ba 455.403	0.004	0.01
Ca 396.847	0.03	0.10
Ca 315.887	0.67	2.2
Cd 214.439	0.01	0.05
Co 238.892	0.04	0.14
Cr 267.716	0.03	0.10
Cu 327.395	0.02	0.06
Fe 238.204	0.03	0.11
K 766.491	9.4	31
Mg 279.553	0.01	0.05
Mn 257.610	0.02	0.06
Mo 202.032	0.05	0.16
Na 589.592	3.1	10
Ni 231.604	0.09	0.28
P 213.618	1.2	3.9
Pb 220.353	0.34	1.1
S 181.972	3.9	13
Se 196.026	0.61	2.0
Si 251.611	0.15	0.48
Sr 421.552	0.002	0.006
Ti 334.941	0.01	0.03
Tl 190.794	0.34	1.1
V 292.401	0.08	0.27
Zn 213.857	0.03	0.09
Al 396.152	0.13	0.42

CRM and spike recoveries test

To confirm the accuracy of the sample preparation and quantitative method, the NIST 1566b Oyster Tissue SRM was analyzed in triplicate using the 5800. As shown in Table 5, recoveries for all elements (except Al) measured above the LOQ were within 100 ±10% of the expected value. Even for Al, recoveries were within 100 ±15% using optimized microwave digestion parameters and avoiding the use of hydrofluoric (HF) acid.

Table 5. Recovery of elements measured in NIST 1566b Oyster Tissue SRM by the Agilent 5800 VDV ICP-OES. "NA" indicates the lack of a certified or reference value.

Element and Wavelength (nm)	Certified or Reference Value (mg/kg)	Measured Concentration (mg/kg)	Recovery (%)
Al 396.152**	197	168	85
As 188.980	7.65	7.56	98
B 249.678	4.5	4.59	102
Ba 455.403	8.6	8.08	94
Ca*	838	821	98
Cd 214.439	2.48	2.46	99
Co 238.892	0.371	0.38	103
Cr 267.716	NA	-	-
Cu 327.395	71.6	67.03	93
Fe 238.204	206	195	94
K 766.491	6520	6406	98
Mg*	1085	1030	94
Mn 257.610	18.5	17.6	95
Mo 202.032	NA	-	-
Na 589.592	3297	3208	97
Ni 231.604	1.04	1.004	98
P 213.618	NA	-	-
Pb 220.353	0.308	<LOQ	-
S 181.972	6890	7178	104
Se 196.026	2.06	2.1	101
Si 251.611	NA	-	-
Sr 421.552	6.8	6.34	93
Ti 334.941	12.2	11.09	90
Tl 190.794	NA	-	-
V 292.401	0.577	0.59	102
Zn 213.857	1424	1375	96

*MultiCal. **Al is reported below the expected value as the 1566b Oyster Tissue SRM contains a relatively high amount of aluminosilicates that would require HF for complete digestion.

A digested sample of the unprocessed frass sample was spiked with each analyte at a concentration that was representative of the concentration in the unspiked samples. All recoveries were within 100 ±10% of the expected concentration, as shown in Table 6. The excellent spike recovery data demonstrates the ability of the 5800 to accurately measure analytes at analytically relevant concentrations in the sample matrix.

Table 6. Spike recovery data for the unprocessed frass sample. All elements were spiked post-digest.

Element and Wavelength (nm)	Unspiked Concentration (mg/L)	Spike Concentration (mg/L)	Measured Concentration (mg/L)	Recovery (%)
Al 396.152	5.91	10.5	17.2	108
As 188.980	0.006	0.5	0.489	97
B 249.678	0.125	0.5	0.628	101
Ba 455.403	0.159	0.5	0.612	91
Ca*	378	200	567	95
Cd 214.439	0.0003	0.5	0.476	95
Co 238.892	0.006	0.5	0.471	93
Cr 267.716	0.020	0.5	0.505	97
Cu 327.395	0.188	0.5	0.652	93
Fe 238.204	8.90	10.5	18.7	93
K 766.491	85.1	50	136	101
Mg*	20.2	100	115	95
Mn 257.610	1.47	5.5	6.69	95
Mo 202.032	0.019	0.5	0.484	93
Na 589.592	34.3	50	83.4	98
Ni 231.604	0.022	0.5	0.474	90
P 213.618	54.7	20	73.7	95
Pb 220.353	0.001	0.5	0.468	93
S 181.972	25.0	20	44.4	97
Se 196.026	0.003	0.5	0.506	101
Si 251.611	6.24	5.5	11.6	97
Sr 421.552	0.253	0.5	0.710	91
Ti 334.941	0.163	0.5	0.625	93
Tl 190.794	0.005	0.5	0.468	93
V 292.401	0.016	0.5	0.487	94
Zn 213.857	2.49	5.5	7.68	94

*MultiCal.

Quantitative results

Following a thorough evaluation of the method, it was used to determine all 26 elements in the insect-related samples. The quantitative results for all sample types are reported in Table 7.

Table 7. Agilent 5800 VDV ICP-OES averaged quantitative data for five sample-types related to the production of insect-derived protein ingredients. Concentration units: mg/kg.

Element and Wavelength (nm)	Organic Waste	Black Soldier Fly Larvae	Insect Meal	Unprocessed Frass	Frass Pellets
Al 396.152	112	49	19.07	1963	576
As 188.980	0.709	1.23	1.31	1.55	0.866
B 249.678	1.99	0.47	0.149	14.4	11.8
Ba 455.403	2.13	4.40	4.45	13.2	16.4
Ca*	4031	25159	26419	57253	35803
Cd 214.439	0.0167	0.1371	0.1804	0.0339	0.0209
Co 238.892	0.0065	0.1627	<LOQ	0.7897	0.3932
Cr 267.716	0.448	4.41	0.154	2.63	1.44
Cu 327.395	2.58	7.063	7.072	26.8	19.9
Fe 238.204	117	135	104	1252	697
K 766.491	2783	7596	8977	11051	9349
Mg*	327	1998	2314	2433	1958
Mn 257.610	6.13	60.11	57.5	164	139
Mo 202.032	0.0796	0.2007	0.269	2.36	1.68
Na 589.592	2544	638	660	4296	3368
Ni 231.604	0.2507	0.571	0.0466	3.44	2.12
P 213.618	1415	5295	6036	7117	5904
Pb 220.353	0.189	0.246	0.320	0.414	0.315
S 181.972	901	2376	3038	2759	2544
Se 196.026	0.536	1.23	1.86	1.83	0.811
Si 251.611	140	107	67.7	227	380
Sr 421.552	7.808	38.3	38.0	37.0	25.5
Ti 334.941	6.1	3.43	1.41	11.4	15.4
Tl 190.794	0.0179	<LOQ	0.1588	0.1091	0.0498
V 292.401	0.0965	0.0775	0.0227	3.48	1.36
Zn 213.857	12.06	55.6	84.1	145	167

MultiCal.

Long-term stability

The long-term stability test replicates the performance of an instrument over the course of a typical working day, as required in a high-sample throughput laboratory. Samples were run over eight hours, with a QC check solution analyzed every 10 samples. The measured values were within 4% of the known QC concentration over eight hours, as shown in Figure 3. The stability graph shows no signs of instrumental drift over the run.
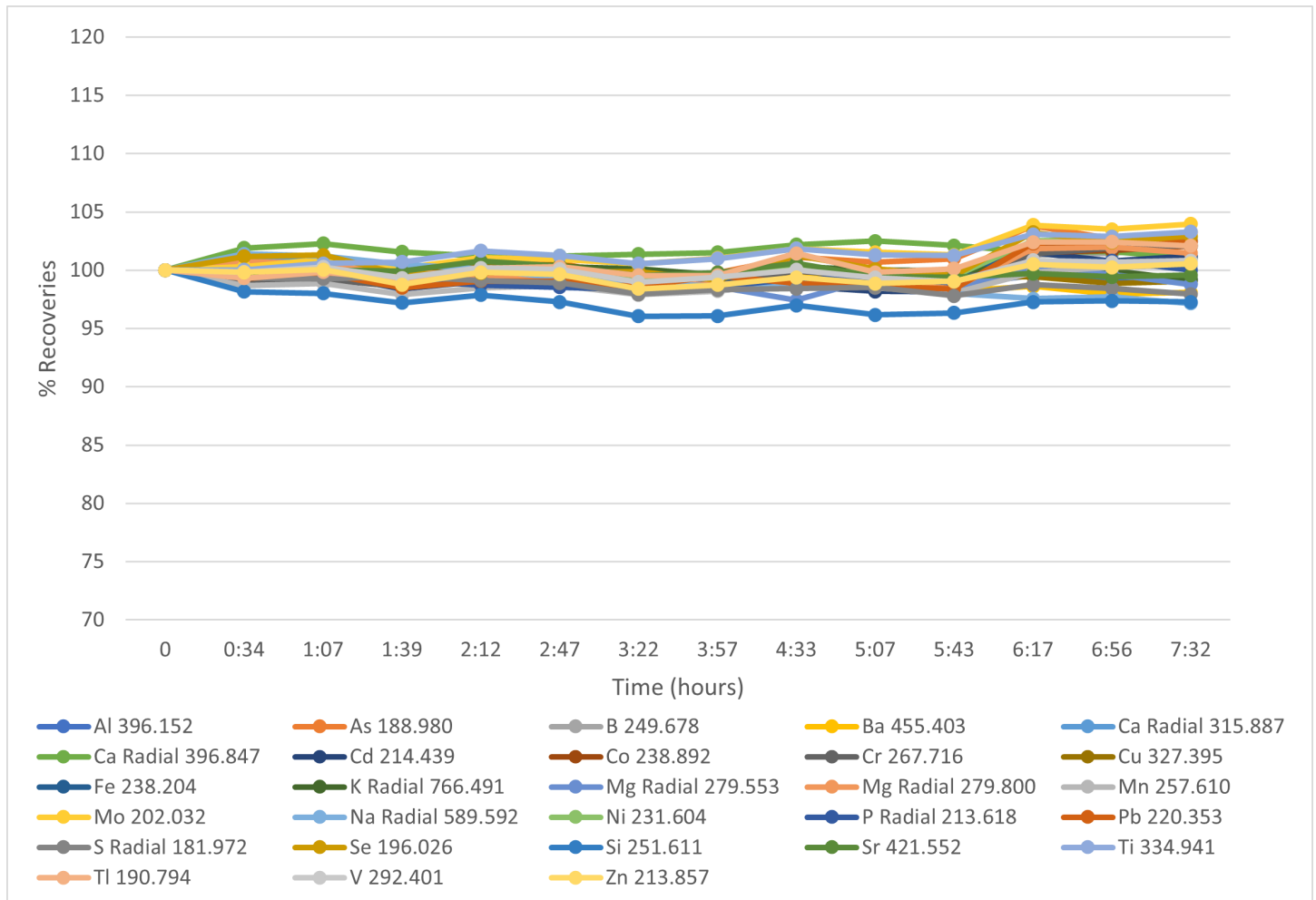

Figure 3. Recovery of QC check solutions over eight hours. Analyte wavelengths were measured within ±4% of the expected value.

Conclusion

This study demonstrates the suitability of the Agilent 5800 VDV ICP-OES for the routine analysis of samples collected at various stages during the production of insect-derived protein and organic fertilizer.

Easy-to-use tools within the Agilent ICP Expert Pro software greatly assisted the analyst in achieving accurate data for the measurement of 26 elements in organic waste, BSF larvae, insect meal, unprocessed frass, and frass pellets.

The tools included :

– IntelliQuant Screening was used to inform the calibration ranges of major and trace analytes and to identify the best wavelengths for some elements during method development.

– Simple-to-use fitted background correction (FBC) provided automatic correction for complex backgrounds.

– Intelligent Rinse automatically optimized the rinse time between samples, saving time and resources.

– MultiCal combined sensitive and less sensitive wavelengths for Ca and Mg to extend the linear dynamic range of the elements.

The accuracy and repeatability of the method was demonstrated by recoveries of the NIST 1566b Oyster Tissue SRM and post-digestion spikes of the samples within 100 ± 10% for most elements. The long-term stability test based on recoveries of the QC solutions demonstrated high accuracy and lack of drift over eight hours. The excellent instrument robustness was due to the stable performance of the solid-state radio frequency system and the vertical torch orientation of the 5800 VDV ICP-OES.

Quantitative data generated by the 5800 ICP-OES method can inform the development of the emerging insect-farming industry and regenerative farming practices. Accurate and reliable data sets are also useful in advance of any potential sector-specific regulations that may be introduced in the future.

References

1. Naser El Deen, S.; van Rozen, K.; Elissen, H.; van Wikselaar, P.; Fodor, I.; van der Weide, R.; Hoek-van den Hil, E.F.; Rezaei Far, A.; Veldkamp, T. Bioconversion of Different Waste Streams of Animal and Vegetal Origin and Manure by Black Soldier Fly Larvae *Hermetia illucens* L. (*Diptera: Stratiomyidae*). *Insects* **2023**, *14*(2), 204; https://doi.org/10.3390/insects14020204

2. International Platform of Insects for Food and Feed (IPIFF), Valorisation of insect frass as fertiliser – an overview, Insect frass as fertiliser – EU Insect Producer Guidelines – IPIFF (accessed May 2024)

3. Riles, P., Multi-Element Analysis of Trace Metals in Animal Feed using ICP-OES, Agilent publication, 5994-0215EN

4. Oppedisano, D., Rapid Multi-Elemental Analysis of Fertilizers using the Agilent 5110 VDV ICP-OES, Agilent publication, 5994-0600EN

5. Agilent ICP Expert Software: Powerful software with smart tools for ICP-OES, Agilent publication, 5994-1517EN

6. Agilent IntelliQuant Screening, Smarter and quicker semiquantitative ICP-OES analysis, Agilent publication, 5994-1518EN

7. Intelligent Rinse for ICP-OES, Increase productivity and reduce errors, Agilent publication, 5991-8456EN

8. Fitted Background Correction (FBC) - Fast, Accurate and Fully Automated Background Correction, Agilent publication, 5991-4836EN

Agilent part numbers

Description	Part Number
Easy-fit torch one piece for 5000 Series vertical dual view ICP-OES	G8010-60228
Double-pass spray chamber, glass cyclonic design with ball joint socket and UniFit drain outlet, for Agilent 5000 series ICP-OES	G8010-60256
SeaSpray concentric nebulizer for Agilent 5000 series ICP-OES	G8010-60255
Peristaltic pump tubing, PVC, white/white, 12/pk	3710034400
Peristaltic pump tubing, PVC, orange/green, 12/pk	3710068300
Peristaltic pump tubing, PVC, blue/blue, 12/pk	3710034600
Reagent uptake capillary tube 1.6 mm od x 1.0 mm id x 1400 mm long with heavy PTFE sinker, 1/pk	G8494-60007
Nebulizer capillary tubing, per m.	2410020500
UniFit drain connector, 2.0 mm od x 0.86 mm id, 3/pk	G8010-80036
Drain tubing for spray chamber waste, 0.12" ID x 0.062" thick, per m.	3710024600
Clip to secure the drain tubing	G8010-40026
Agilent 10,000 ppm single element stock solution for Al	5190-8352
Agilent 10,000 ppm single element stock solution for As	5190-8356
Agilent 10,000 ppm single element stock solution for B	5190-8364
Agilent 10,000 ppm single element stock solution for Ba	5190-8358
Agilent 10,000 ppm single element stock solution for Ca	5190-8368
Agilent 10,000 ppm single element stock solution for Cd	5190-8366
Agilent 10,000 ppm single element stock solution for Co	5190-8376
Agilent 10,000 ppm single element stock solution for Cr	5190-8374
Agilent 10,000 ppm single element stock solution for Cu	5190-8378
Agilent 10,000 ppm single element stock solution for Fe	5190-8402
Agilent 10,000 ppm single element stock solution for K	5190-8432
Agilent 10,000 ppm single element stock solution for Mg	5190-8412
Agilent 10,000 ppm single element stock solution for Mn	5190-8414
Agilent 10,000 ppm single element stock solution for Mo	5190-8418
Agilent 10,000 ppm single element stock solution for Na	5190-8454
Agilent 10,000 ppm single element stock solution for Ni	5190-8422
Agilent 10,000 ppm single element stock solution for P	5190-8428
Agilent 10,000 ppm single element stock solution for Pb	5190-8406
Agilent 10,000 ppm single element stock solution for S	5190-8209
Agilent 10,000 ppm single element stock solution for Se	5190-8448
Agilent 10,000 ppm single element stock solution for Si	5190-8450
Agilent 10,000 ppm single element stock solution for Sr	5190-8207
Agilent 10,000 ppm single element stock solution for Ti	5190-8224
Agilent 10,000 ppm single element stock solution for Tl	5190-8217
Agilent 10,000 ppm single element stock solution for V	5190-8228
Agilent 10,000 ppm single element stock solution for Zn	5190-8234
Agilent 10,000 ppm single element stock solution for Y	5190-8232
Agilent Multi-element Quality Control Standard 27	5190-9418

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