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Unique Benefits of Orbitrap MS Technology for the Comprehensive Analysis of Polar and Non-polar Pesticides

Richard J .Fussell[1], Carmen Ferrer[2] and Sergio Guazzotti[1]

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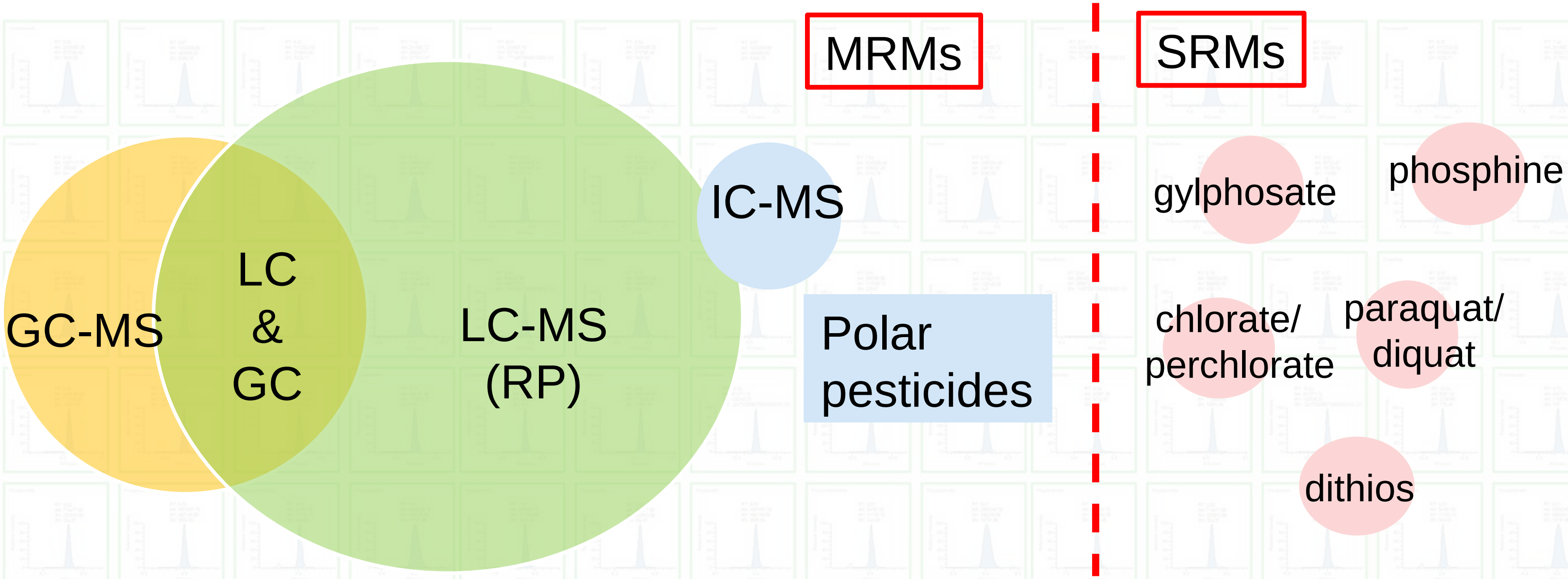
Outline

- Overview of Pesticides workflow
- Features of the different Thermo Scientific™ Orbitrap™ MS Technologies
- Benefits of Orbitrap MS Technology
  - Non targeted and targeted acquisition of small molecules
  - Detection, quantification and identification
  - Retrospective analysis
- Examples to demonstrate the performance of systems

Comprehensive Analysis of Pesticide Residues



- **Targeted acquisition: expected residues**
  - QQQ provides the selectivity and sensitivity to meet MRL requirements.
- **Non-targeted acquisition**: **expected, suspected and unexpected residues**
  - High Resolution Accurate Mass (HRAM) MS provides:
    - Similar sensitivity
    - Improved selectivity & quantification
    - Simplicity of FS method set-up
    - Increased scope
    - Retrospective analysis
    - Flexibility in fragmentation (LC-MS)

Workflow- Analysis of Extracts

Thermo Scientific™ TSQ Endura™ Triple Quadrupole Mass Spectrometer

IC-(Thermo Scientific™ Dionex™ ICS-5000+ Reagent-Free™ HPIC™ system) MS/MS

QuEChERS
NL
SweEt

Thermo Scientific™ TSQ™ 8000 Evo Triple Quadrupole GC-MS/MS

Targeted analysis- triple quadrupole MS/MS

QuPPe
methanol/water
(polar pesticides)

Simultaneous Targeted & Non-Targeted Analysis: Orbitrap-MS
(detection, quantification, identification, screening)

Thermo Scientific™ Exactive™ GC Orbitrap™ GC-MS

Thermo Scientific™ Q Exactive™ Focus Hybrid Quadrupole-Orbitrap Mass Spectrometer

Thermo Scientific™ Dionex™ Integrion™ HPIC™ System - can be coupled to Orbitrap MS

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Redefining Routine Pesticides Analysis

Exactive GC system

Redefining Routine GC-MS

EI/CI; Full-scan; Timed-SIM

EI Spectra searchable against the NIST Library

Resolving Power

Up to 60,000 at *m/z* 200

Mass Accuracy

< 1ppm

Sensitivity

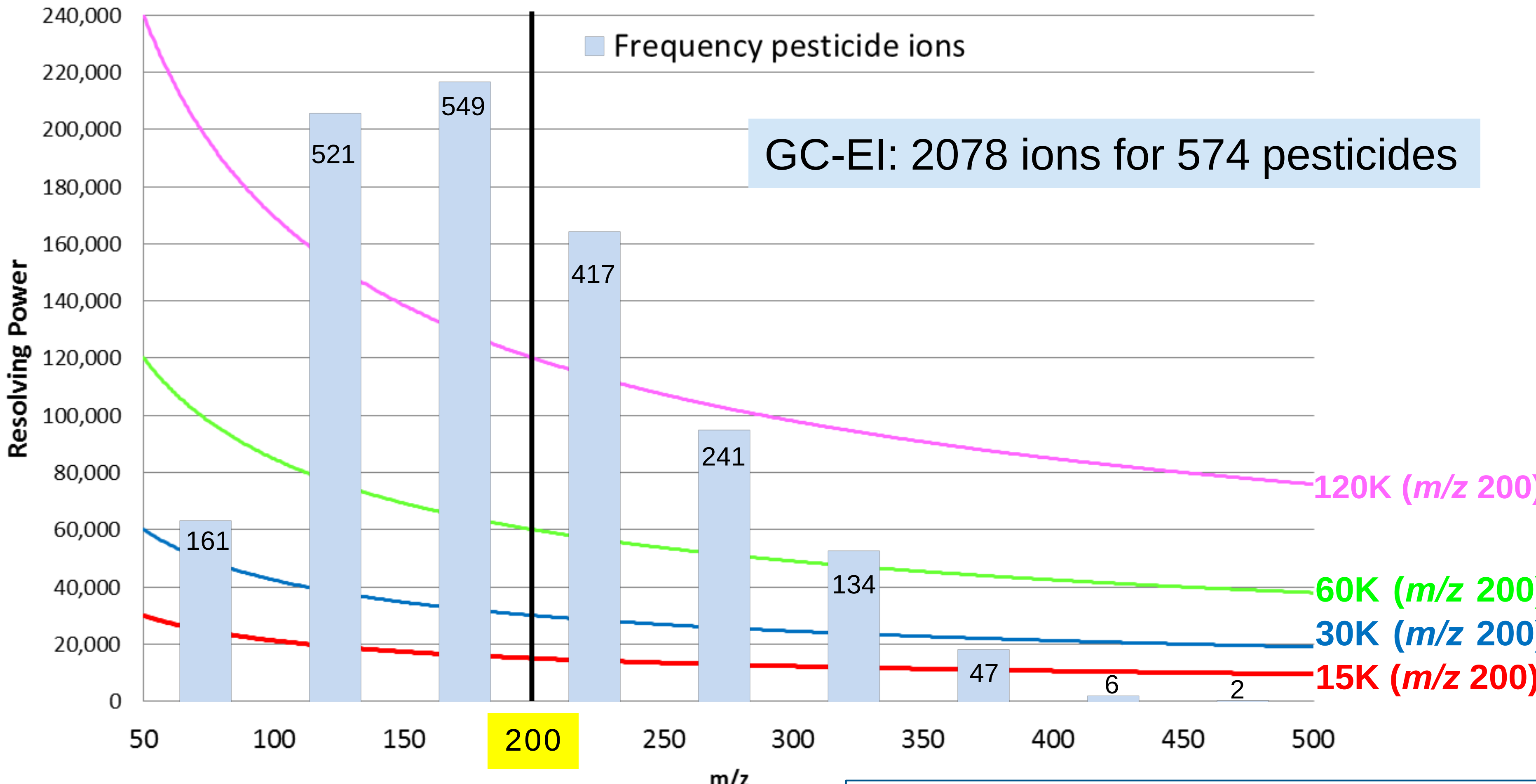
ppt

Dynamic Range

>6 orders

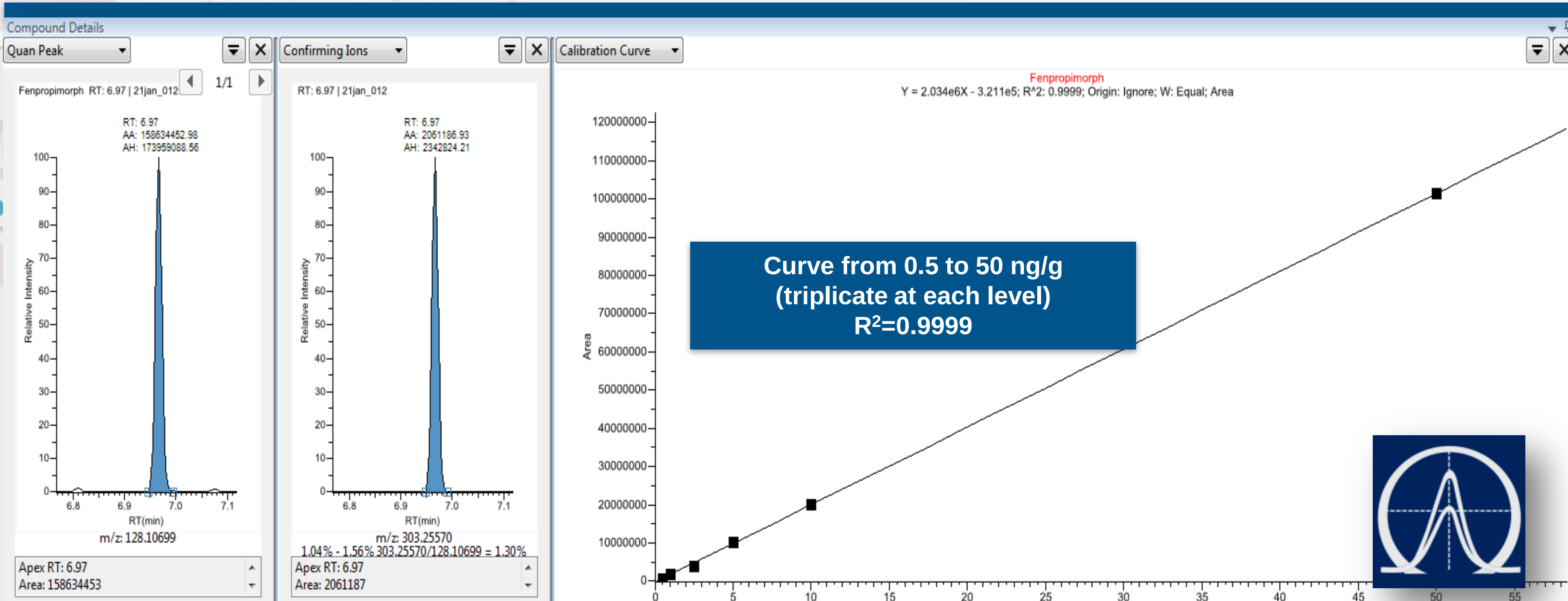
QE GC-Orbitrap MS Resolving Power

Resolving power ~1/√*m/z*



Data courtesy of Dr Hans Mol, Rikilt Wageningen, UR

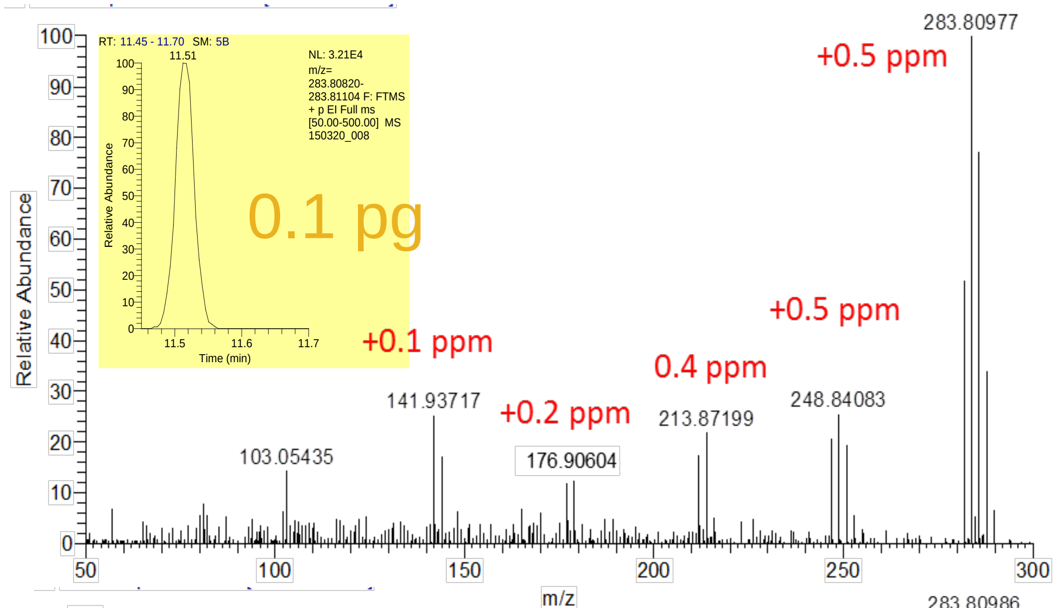
GC-HRAM Linearity

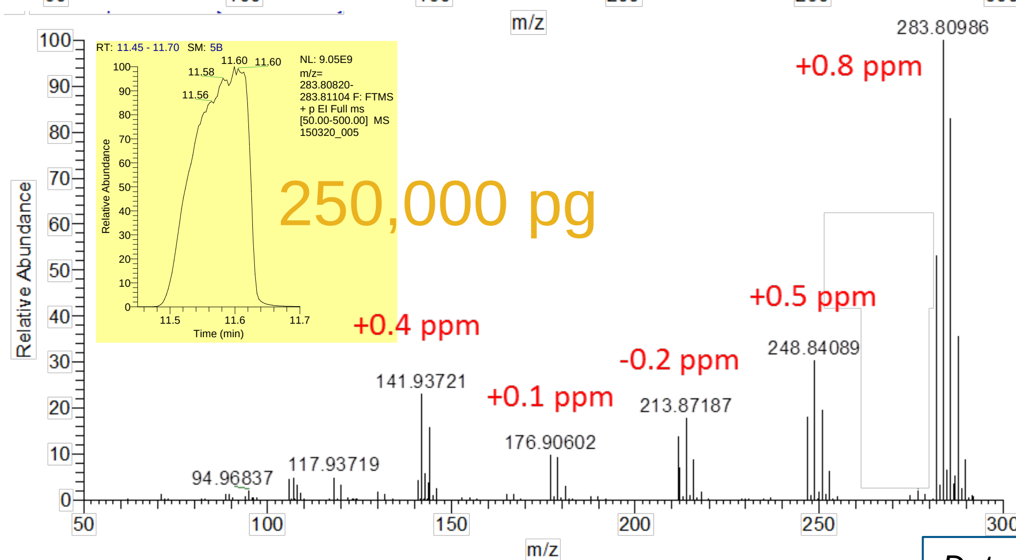


Fenpropimorph calibration curve in leek matrix.

- For all pesticides, the coefficient of determination (R^2) was > 0.99 with an average value of R^2 = 0.997

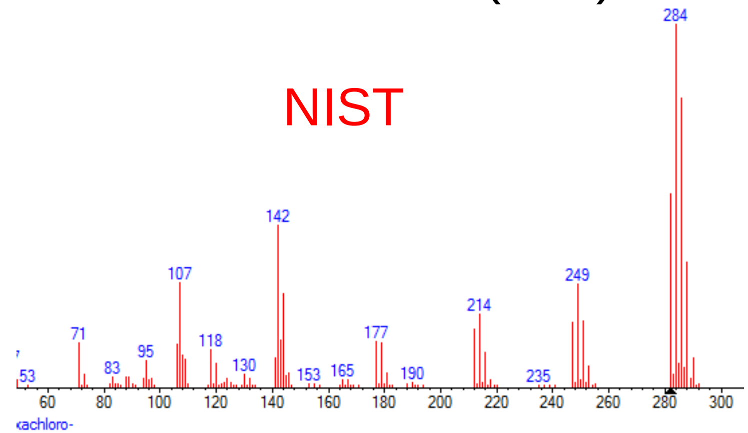
Spectral Quality vs Amount Injected





Solvent standard hexachlorobenzene (60K)

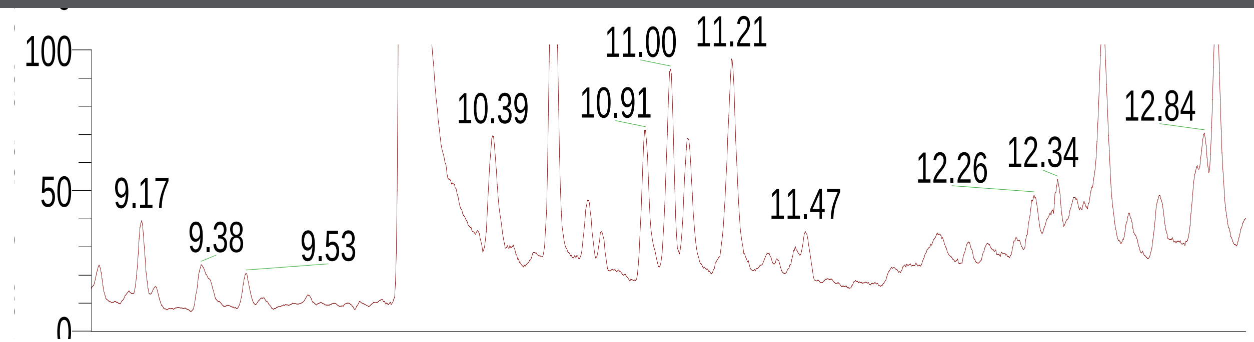
NIST



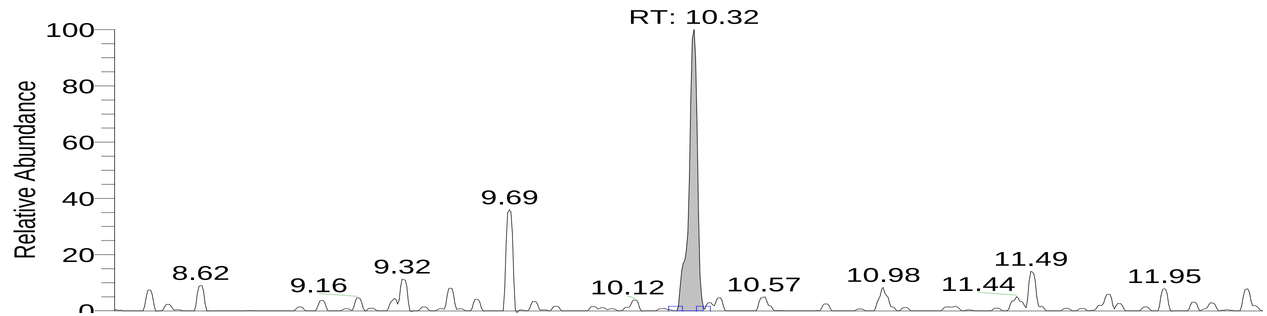
Data courtesy of Dr Hans Mol, Rikilt Wageningen, UR

Selectivity (chlorpropham in leek, 10 ppb)

Nominal mass
Full scan MS
XIC *m/z* ± 0.5 Da
127 ± 0.5 Da

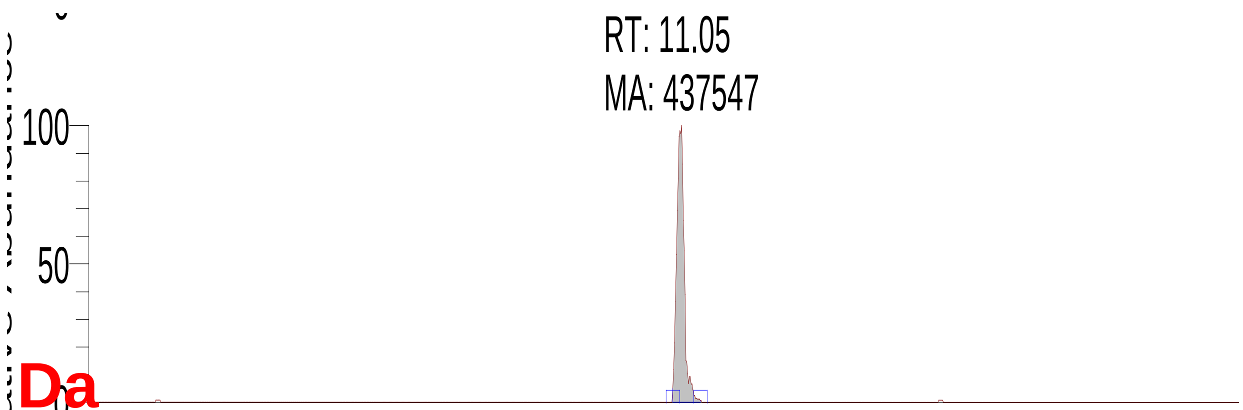


Nominal Mass
MS/MS
213 → 127



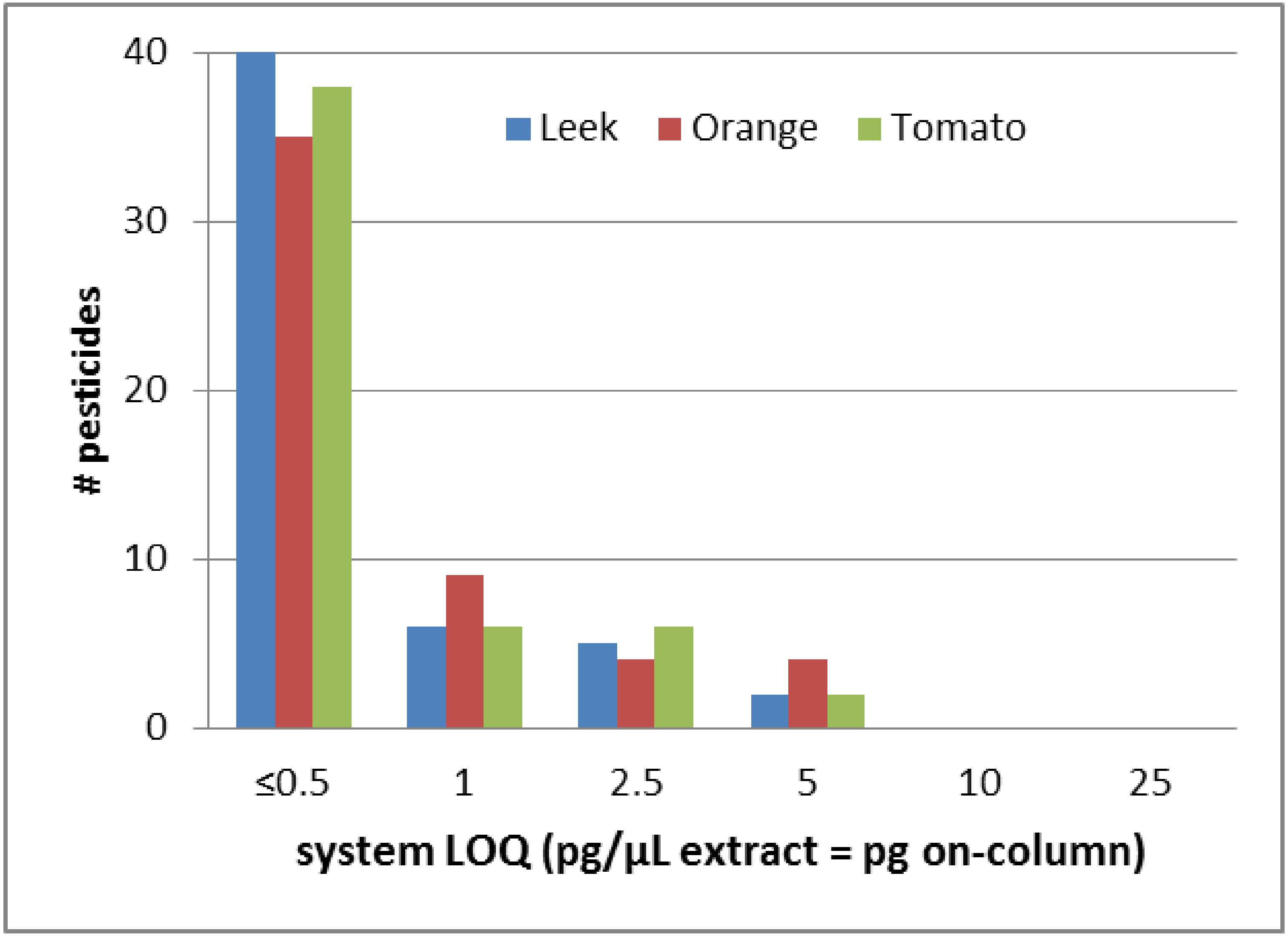
HRAM
Full scan MS
XIC *m/z* ± 5 ppm

127.01833 ± 0.0006 Da



Data courtesy of Dr Hans Mol, Rikilt Wageningen, UR

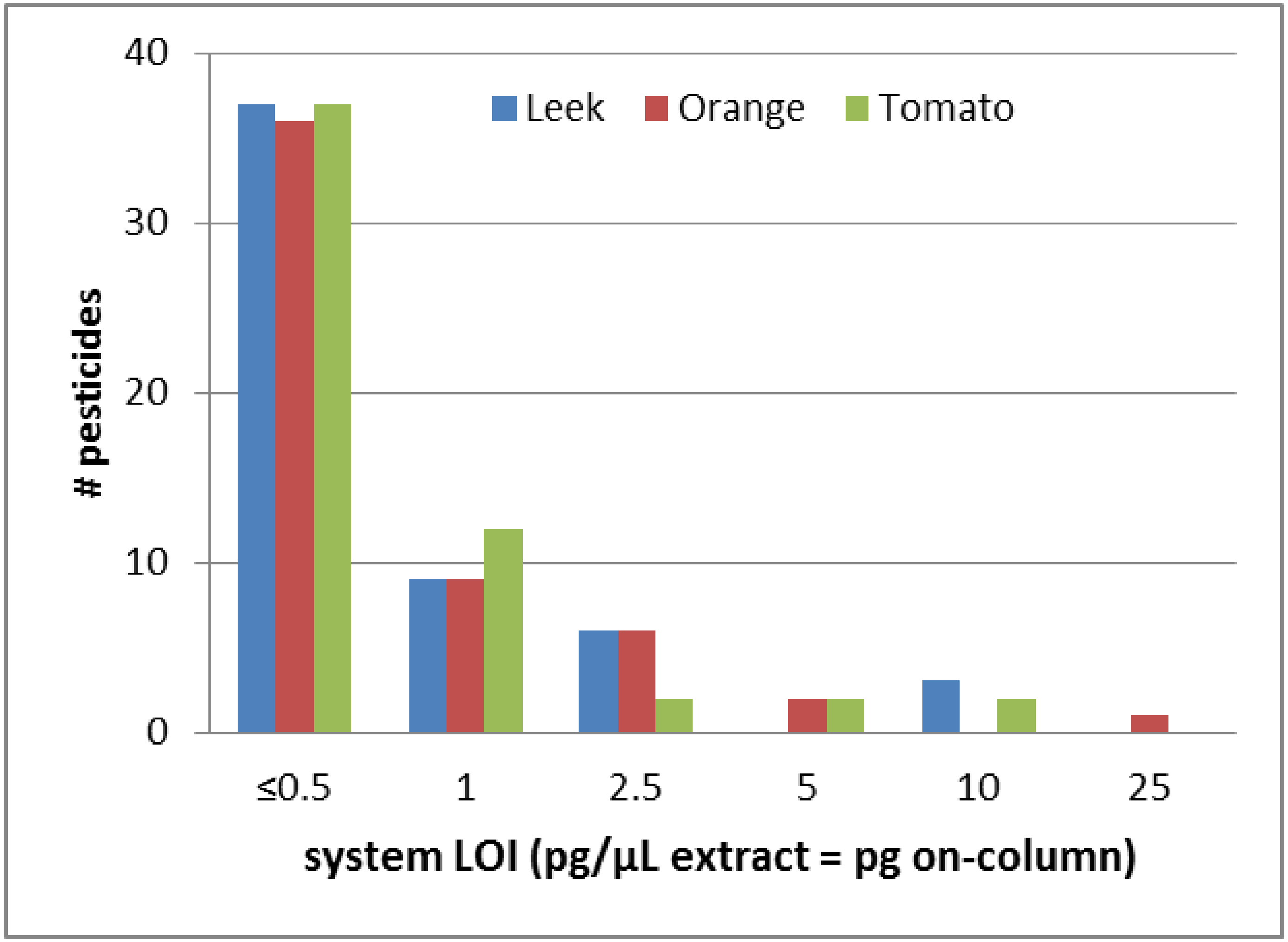
Limit of Quantification: Exactive GC system



QuEChERS - 1µL

Data courtesy of Dr Hans Mol, Rikilt Wageningen, UR

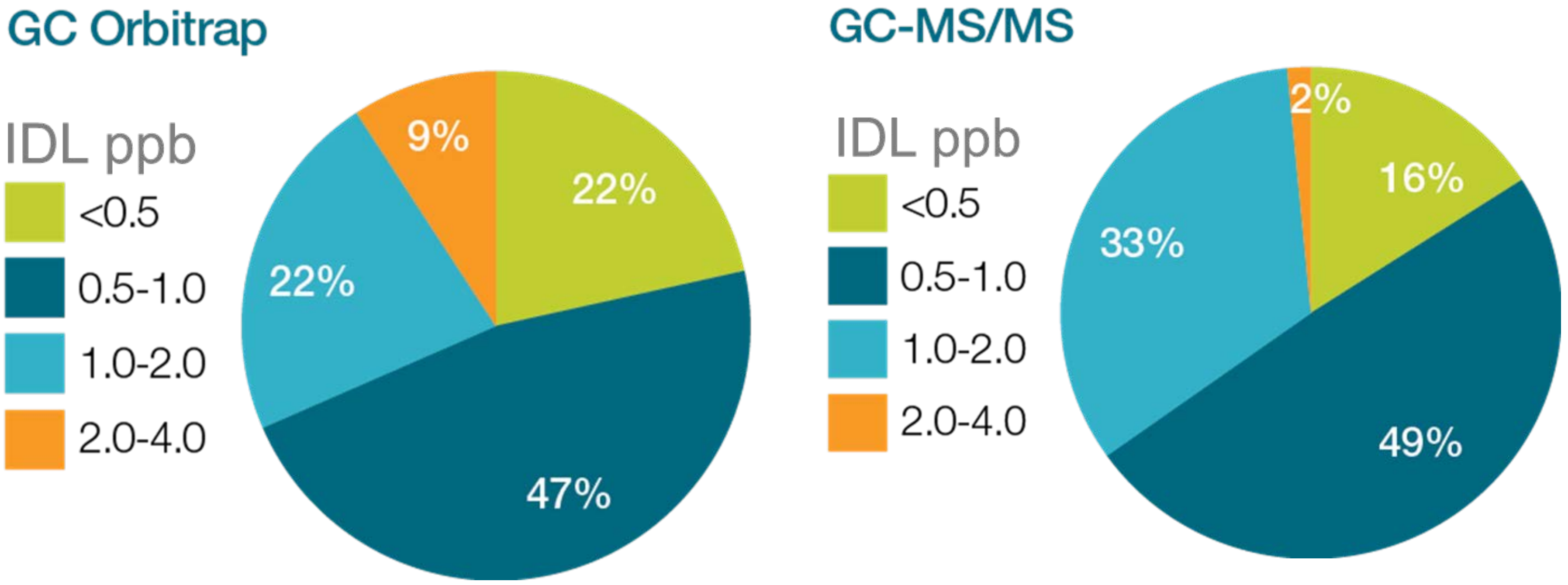
Limit of Identification: Exactive GC system



QuEChERS - 1µL

Data courtesy of Dr Hans Mol, Rikilt Wageningen, UR

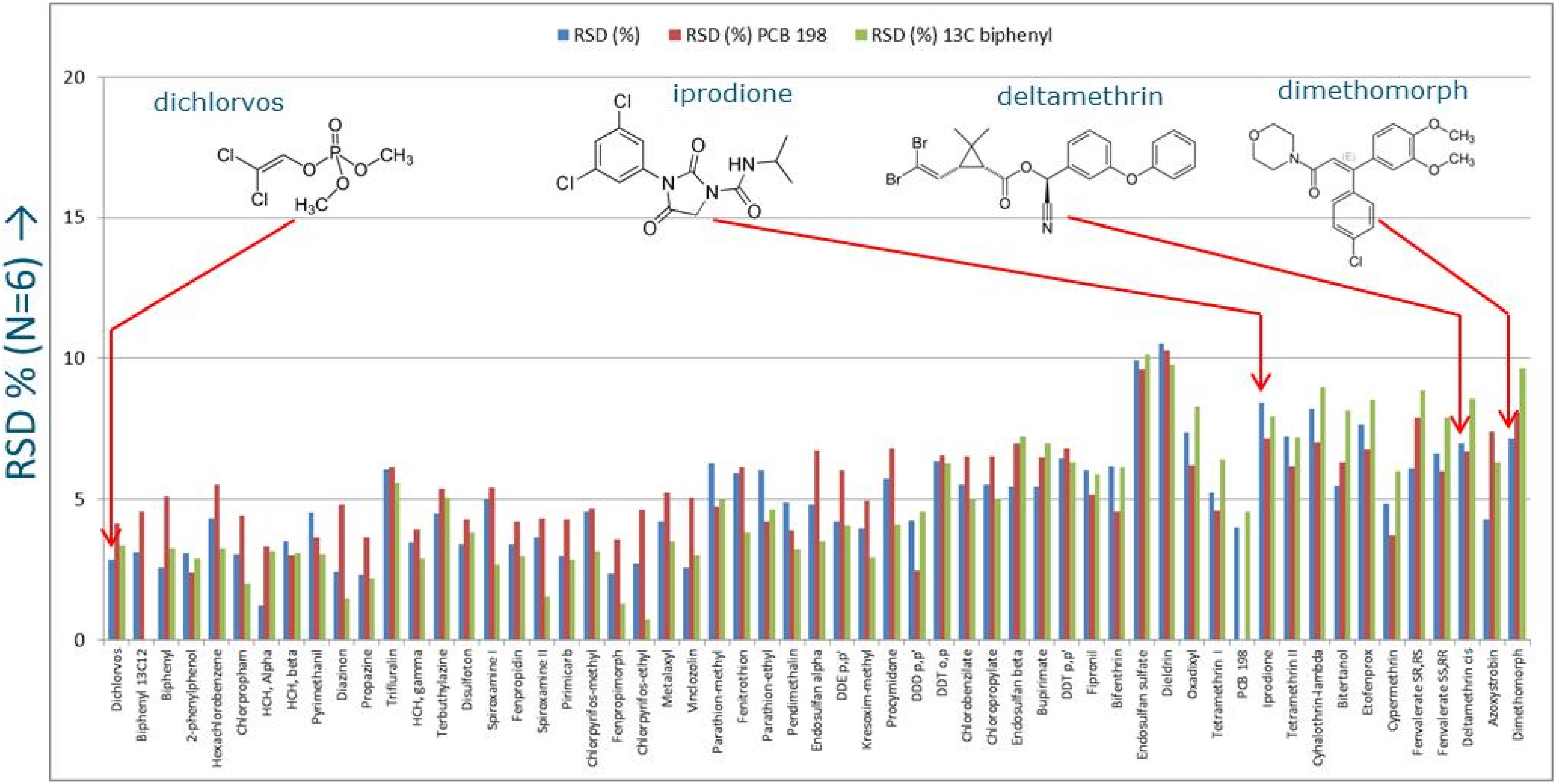
150 compounds in mixed vegetable matrix



Triple-quadrupole-level sensitivity possible with a non-target acquisition

*Acquired on the Q Exactive GC system – the Exactive GC system provides equivalent performance.

Repeatability of Injection: LVI (5µL)



5 µL QuEChERS (ACN) extract of leek
Various pesticides, 25 pg/µL

Data courtesy of Dr Hans Mol, Rikilt Wageningen, UR

Automated Qualitative Screening Workflows

- Quantitative method with all associated AQC for usual suspects (~100)
- Automated qualitative screening: lower AQC burden for unexpected pesticides
- Same raw data files, but 2 different data processing approaches

1. Library: match of EI-spectra
deconvolution of HR spectra
$\Rightarrow$ cleaned spectrum
Library search (NIST, PEST library)

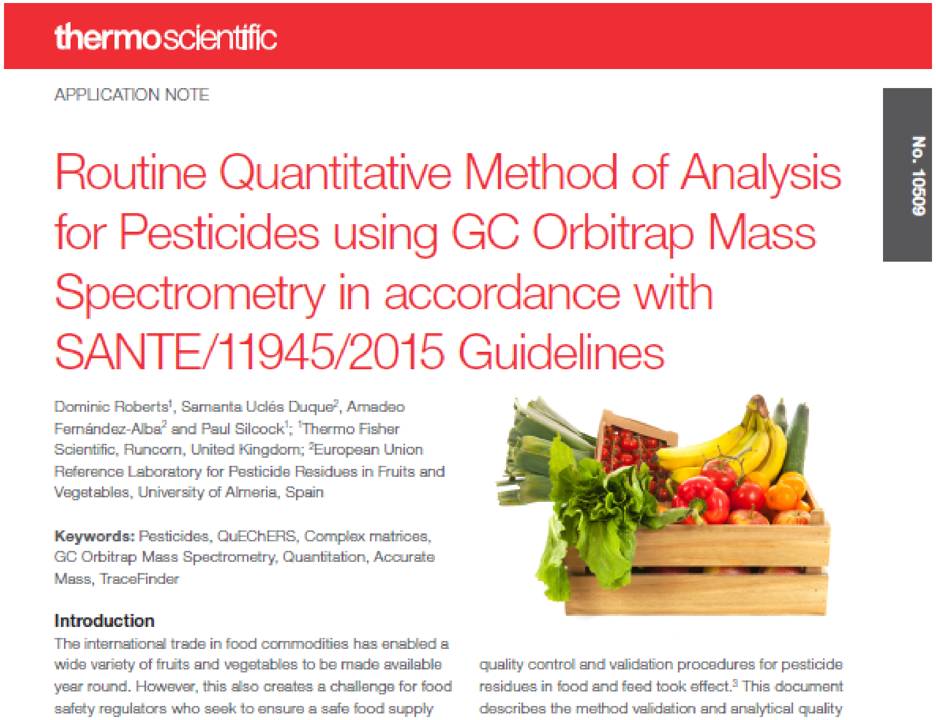
Software: Report if match (SI) > user threshold.
(The analysts manually review hits)

2. Database: RT + 2 exact masses
RT $\pm$ 0.5 min
XICs $\pm$ 5 ppm
2 ions (w/o ratio criterion)

Software:
Report if signal is found for both ions
(The analysts manually review hits)

10 µg/kg	found out of 50
Tomato	47
Orange	44
Leek	43

Data courtesy of Dr Hans Mol, Rikilt Wageningen, UR


thermoscientific

APPLICATION NOTE

No. 10609

Routine Quantitative Method of Analysis for Pesticides using GC Orbitrap Mass Spectrometry in accordance with SANTE/11945/2015 Guidelines

Dominic Roberts[1], Samanta Uclés Duque[2], Amadeo Fernández-Alba[2] and Paul Silcock[1]; [1]Thermo Fisher Scientific, Runcorn, United Kingdom; [2]European Union Reference Laboratory for Pesticide Residues in Fruits and Vegetables, University of Almeria, Spain

Keywords: Pesticides, QuEChERS, Complex matrices, GC Orbitrap Mass Spectrometry, Quantitation, Accurate Mass, TraceFinder

Introduction

The international trade in food commodities has enabled a wide variety of fruits and vegetables to be made available year round. However, this also creates a challenge for food safety regulators who seek to ensure a safe food supply

quality control and validation procedures for pesticide residues in food and feed took effect.[3] This document describes the method validation and analytical quality

Identification Point	Tolerance	Primary ID	Optional additional ID
Retention time	0.1 minutes	✓	
Quan ion	5 ppm	✓	
Identifcation ion	5 ppm	✓	
Ion ratio	< 30%	✓	
Additional ions	5 ppm		✓
Isotopic pattern match	> 70%		✓
NIST spectral match	> 600		✓

51 pesticides were prepared in tomato, leek and orange at concentrations equivalent to 0.5, 1, 2, 5, 10, 20, 50, 100, 200 and 500 µg/Kg.

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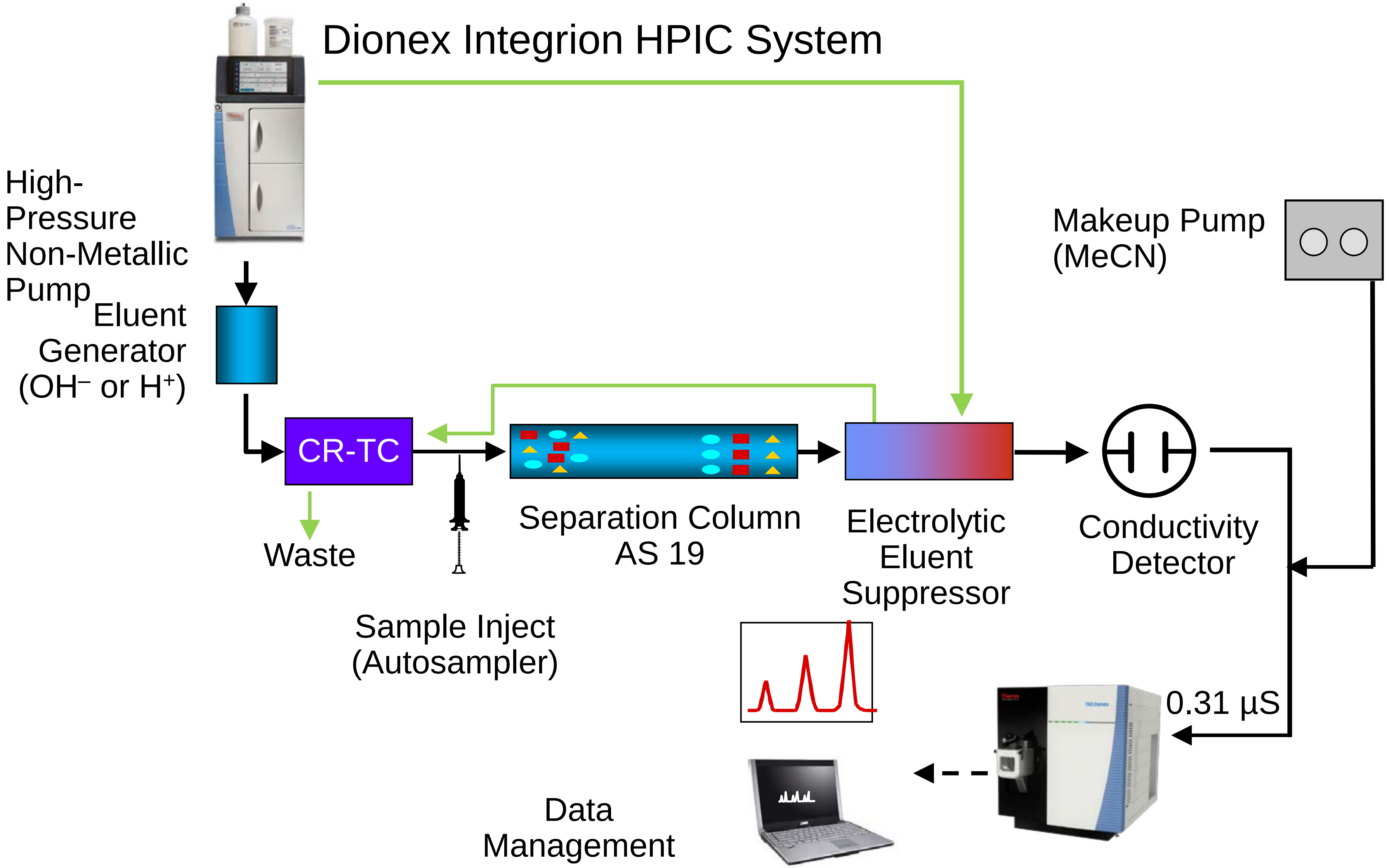
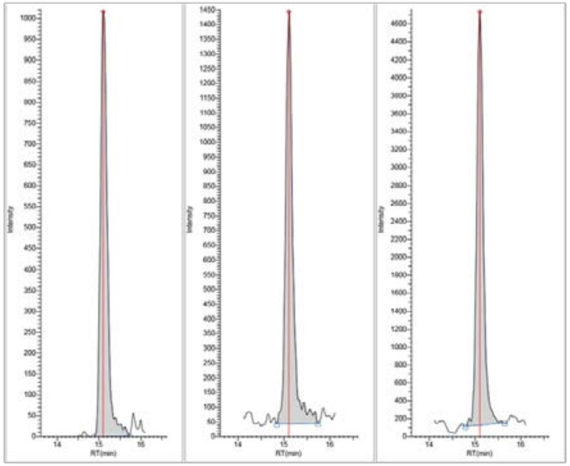
Ion Chromatography-Mass Spectrometry: Polar Ionic Pesticides

IC-MS/MS Configuration



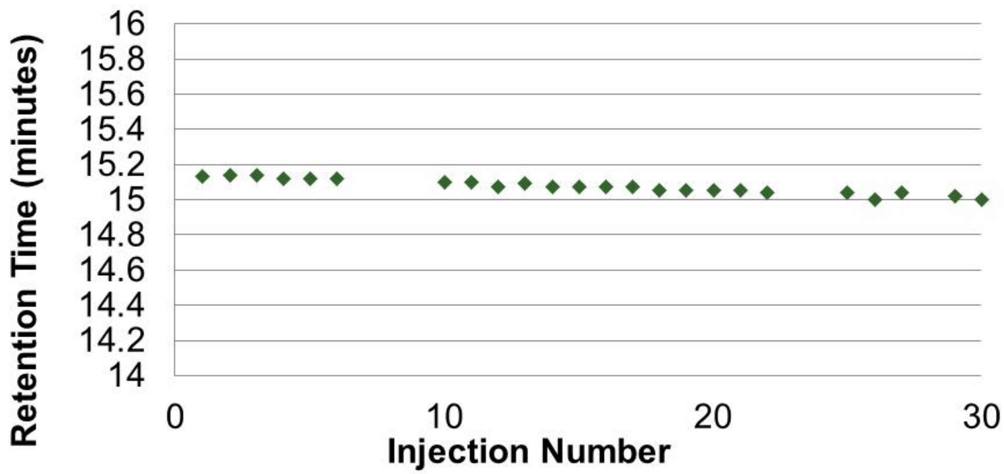
Glyphosate: IC-QQQ Analysis of QuPPe Extracts of Wheat Flour

Glyphosate spiked @ 10 µg/kg

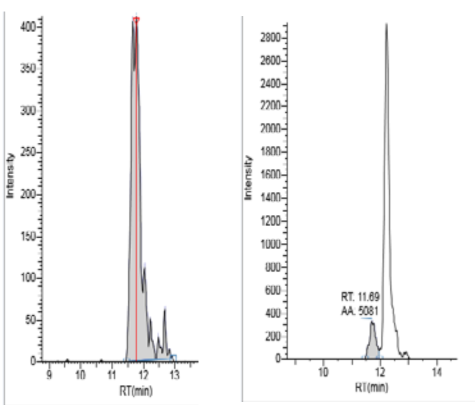


168 >62.9 168 >78.9 168 >149.9

- Stable retention times



AMPA spiked @ 10 µg/kg



110.1>78.9 110.1>62.9

- Multi-analyte capability

Glyphosate	Glufosinate	**Fosetyl**
N-acetyl glyphosate	*N*-acetyl glufosinate	Phosphonic acid
AMPA	3-MPPA	chlorate
N-acetyl AMPA	ethephon	perchlorate

Data Courtesy of Fera Science Ltd UK

Polar Ionic Pesticides (QuPPE) w/wo IS Correction (Grape)

		IS Corrected		Not corrected	
Compound	Conc^{n} (ng/g)	Mean % Rec (n=5)	Mean % RSD	Mean % Rec (n=5)	Mean % RSD
Glyphosate	10	112	15	96	1
	100	111	7	94	1
AMPA†	10	121	10	92	22
	100	108	8	97	3
***N*-acetyl AMPA**	10	100	2	97	6
	100	99	2	96	2
Glufosinate	10	100	16	108	2
	100	109	8	94	2
3-MPPA	10	106	17	90	2
	100	111	7	96	2
***N*-acetyl Glufosinate**	10	104	15	92	4
	100	110	7	98	2
Perchlorate	10	110	17	94	11
	100	113	6	96	1
Chlorate	10	112	19	92	6
	100	115	6	100	2
Ethephon	0.01	114	17	104	7
	0.1	102	10	95	5
Fosetyl-Al	0.2	**IS not available**		98	3
	2			90	2
Phosphonic acid	0.2			102	2
	2			103	2

Data Courtesy of Fera Science Ltd UK

Polar Ionic Pesticides (QuPPE) w/wo IS Correction (wheat flour)

Compound	Conc^{n} (ng/g)	IS Corrected: Mean % Rec (n=5)	IS Corrected: Mean % RSD	Not corrected: Mean % Rec (n=5)	Not corrected: Mean % RSD
Glyphosate	10	104	3	56	9
	100	92	2	48	3
AMPA†	10	69	11	85	4
	100	89	4	80	3
N-acetyl AMPA	10	89	5	97	6
	100	84	2	74	1
Glufosinate	10	120	5	42	31
	100	91	8	104	9
3-MPPA	10	94	5	95	5
	100	88	2	80	4
N-acetyl Glufosinate	10	88	7	98	7
	100	88	2	78	3
Perchlorate	10	107	1	66	2
	100	93	3	56	5
Chlorate	10	91	5	74	3
	100	88	1	67	2
Ethephon	0.01	104	10	66	9
	0.1	87	7	95	6
Fosetyl-Al	0.2	**IS not available**		60	4
	2			72	2
Phosphonic acid	0.2			106	5
	2			97	2

Data Courtesy of Fera Science Ltd UK

IC-MS: The Solution to the Problem Analysis of Polar Pesticides?

- The High Capacity of Dionex Ion-exchange Columns
- The Robustness of Ion-exchange Columns
- Compatibility with Mass Spectrometers
- Independent Results in Compliance with Accepted Guideline Criteria
- A Commitment to Continuous Method Improvement

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Article

Previous

Development and Validation of Ion Chromatography–Tandem Mass Spectrometry-Based Method for the Multiresidue Determination of Polar Ionic Pesticides in Food

Stuart Adams[*†], Jonathan Guest[†], Michael Dickinson[†], Richard J. Fussell[§], Jonathan Beck[⊗], and Frans Schoutsen[⊖]

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[§] Thermo Fisher Scientific, Hemel Hempstead, United Kingdom
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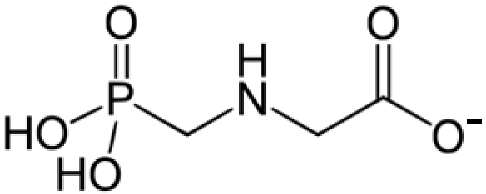
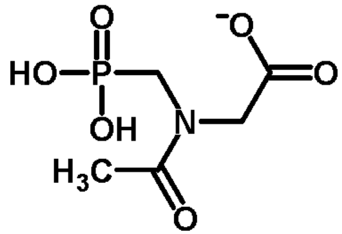
J. Agric. Food Chem., Article ASAP
DOI: 10.1021/acs.jafc.7b00476
Publication Date (Web): April 7, 2017

Stuart Adams *et al*
J. Agric. Food Chem, 2017 on-line

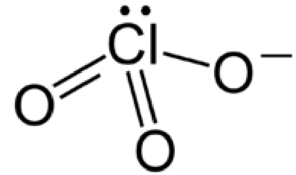
Polar Analytes



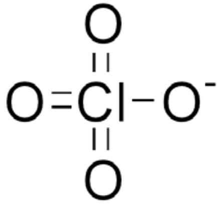
Glyphosate
(*m/z* 168.0067)



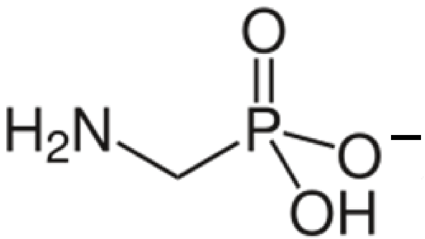
N-acetyl glyphosate
(*m/z* 210.0173)



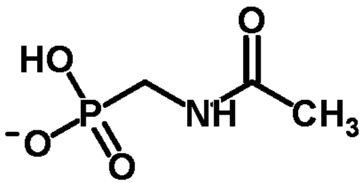
Chlorate
(*m/z* 82.9541)



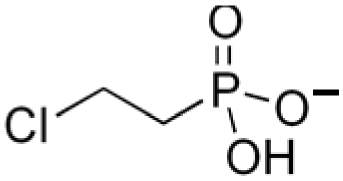
Perchlorate
(*m/z* 98.9491)



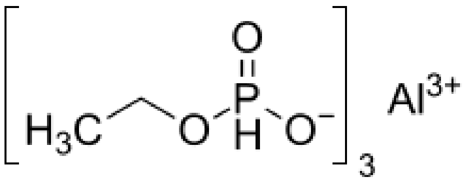
Aminomethylphosphonic acid
(AMPA)
(*m/z* 110.0012)



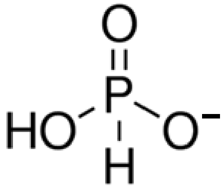
N-acetyl aminomethylphosphonic acid
(N-acetyl AMPA)
(*m/z* 152.0118)



Etephon
(*m/z* 142.9670)



Fosetyl-aluminium
(*m/z* 109.0060)



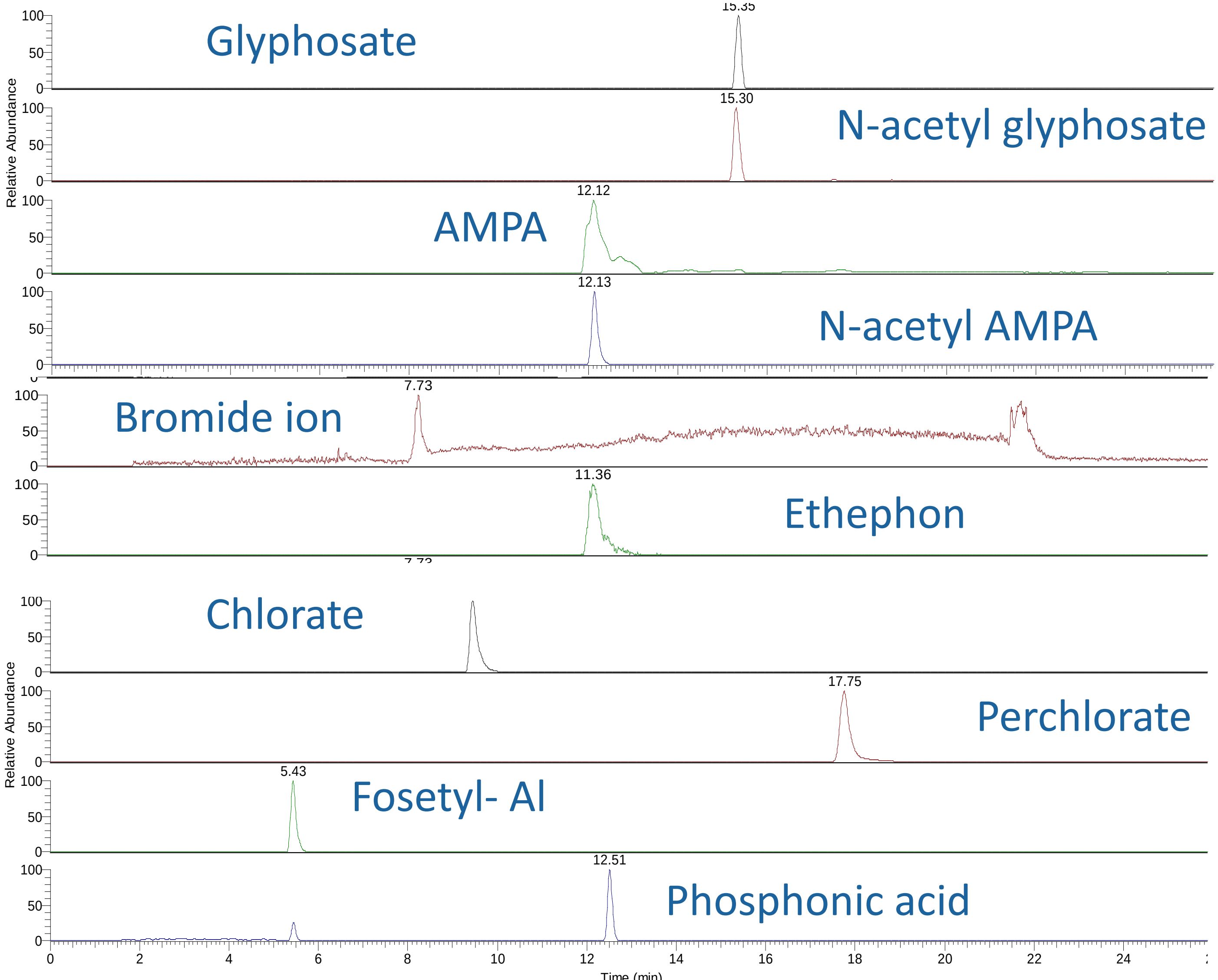
Phosphonic acid
(*m/z* 80.9747)

Br^-

Bromide ion
(*m/z* 78.9189)

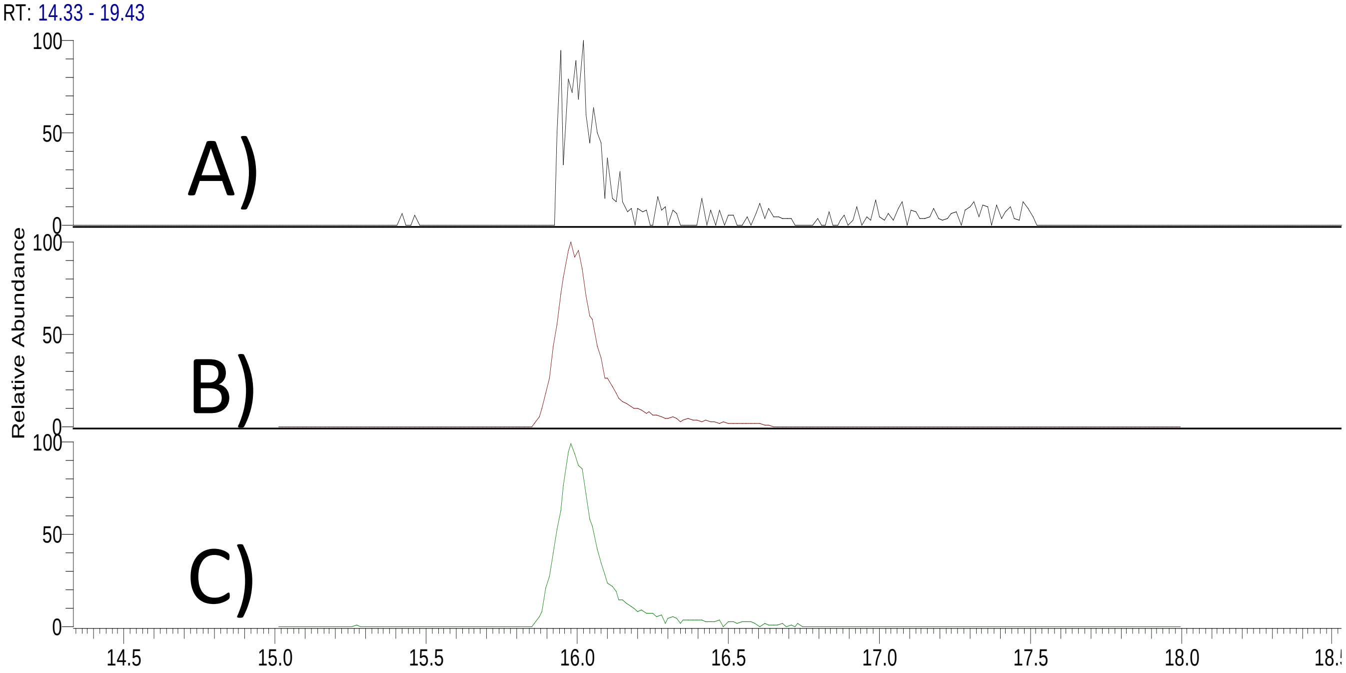
Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain ,

Extracted Ion Chromatograms of Precursor Ions @10 ng/g



Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain ,

Glyphosate- Sensitivity Improvement in MS^2



- 0.01 mg/kg of glyphosate in carrot.

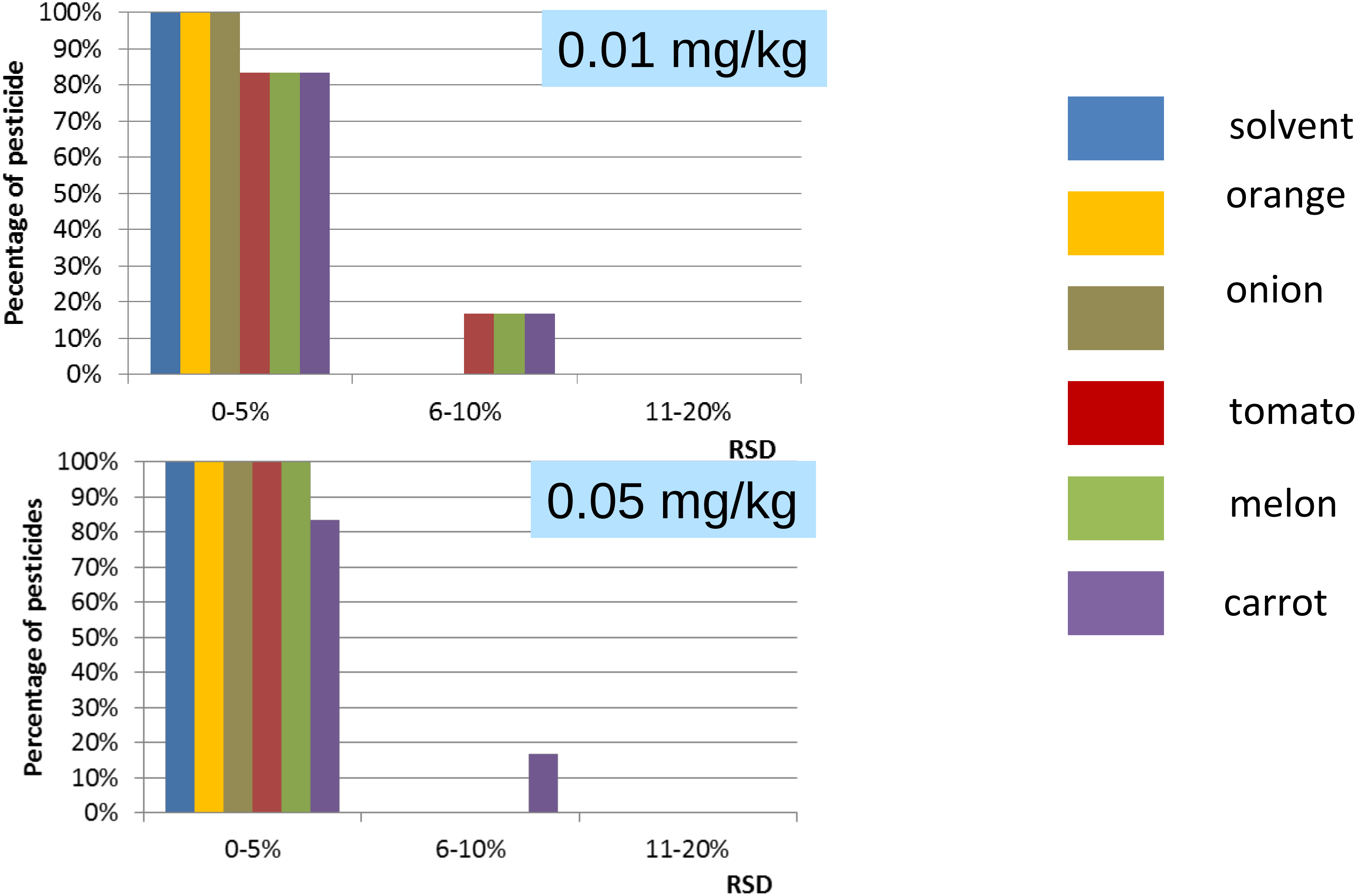
A) 168.0067 ± 5 ppm extracted from full scan MS(*m/z* 78 – 212)

B) 62.9637 ± 5 ppm extracted from PRM MS^2

C) 78.9588 ± 5 ppm extracted from PRM MS^2

Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain ,

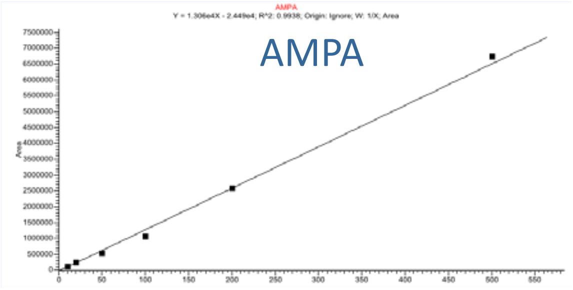
Validation of IC - Orbitrap Method: Peak Area Repeatability

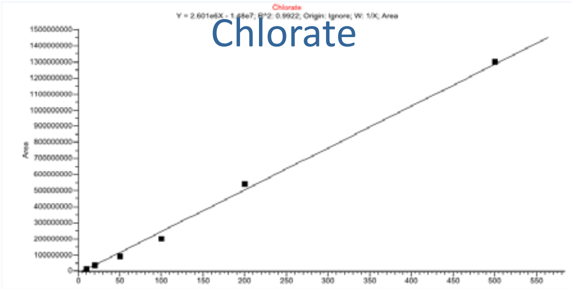


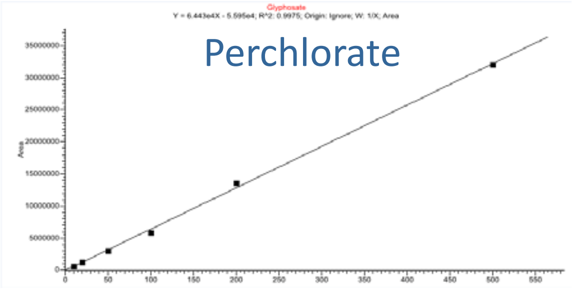
Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain ,

Validation of IC-Orbitrap Method: Linearity

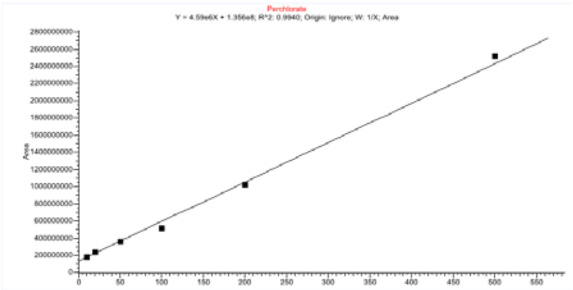
0.01-0.05 mg/kg

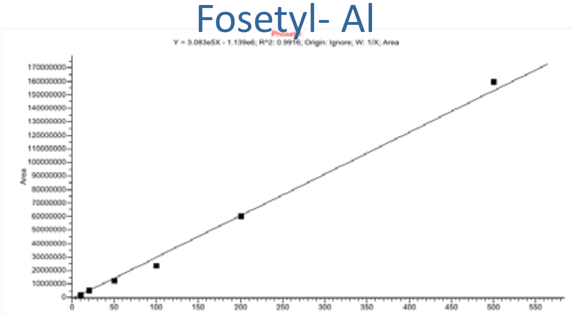




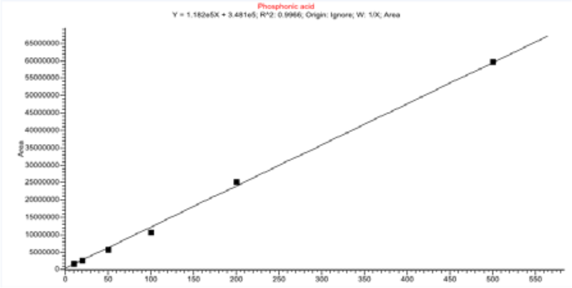


Glyphosate





Phosphonic acid



Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain ,

Modified QuPPe-PO

Weigh sample homogenate in 50 mL centrifuge tube

Fresh fuits and vegetables (high water content):

10 ± 0.1 g

Adjust water content of sample to 10 mL

Add 10 mL MeOH

Add 25 µL IS (20 ppm)

(^{13}C-Glyphosate & $^{18}O_3$-Chlorate)

Shake automatically 5 min

Centrifuge at 4000 rpm for 5 min

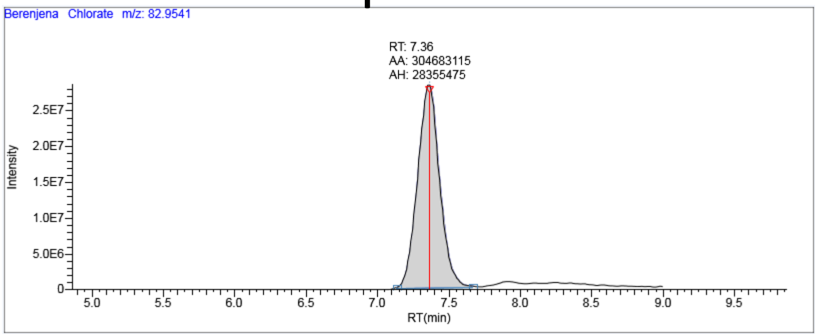
Transfer 4 mL supernatant into a plastic vial

IC-MS analysis

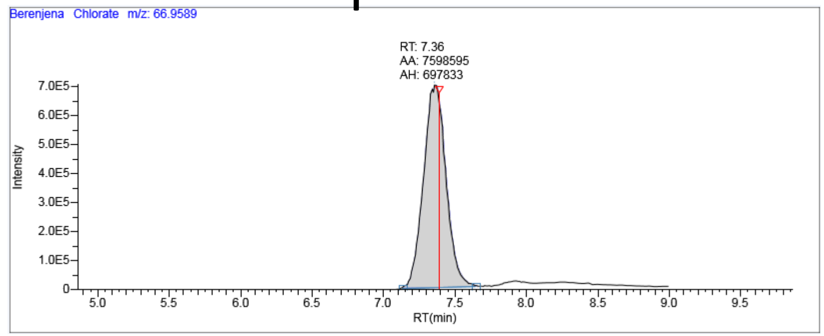
Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain ,

Aubergine 0.51 mg/kg of chlorate

quantifier

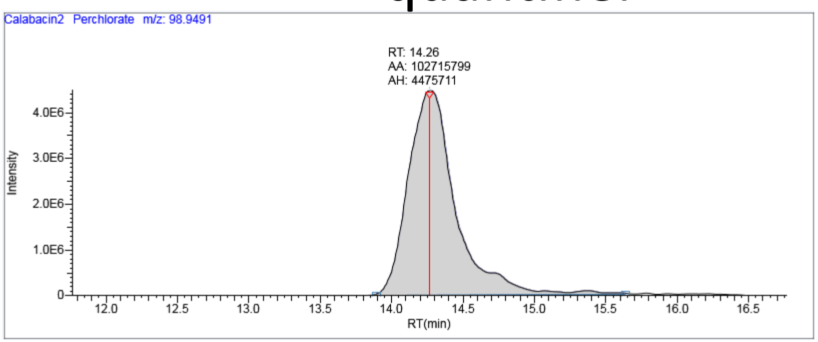


qualifier

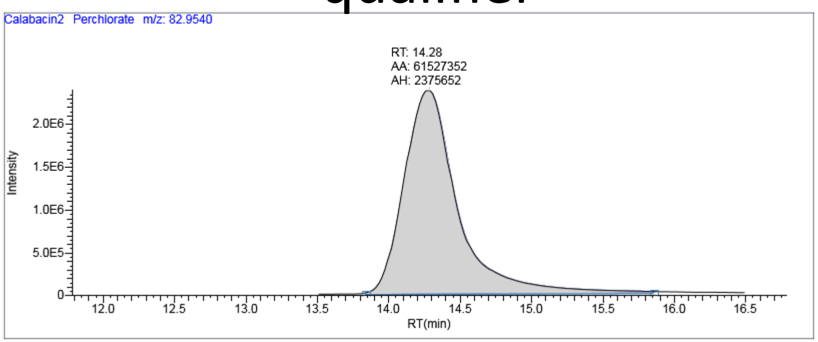


Zucchini 0.075 mg/kg of perchlorate

quantifier



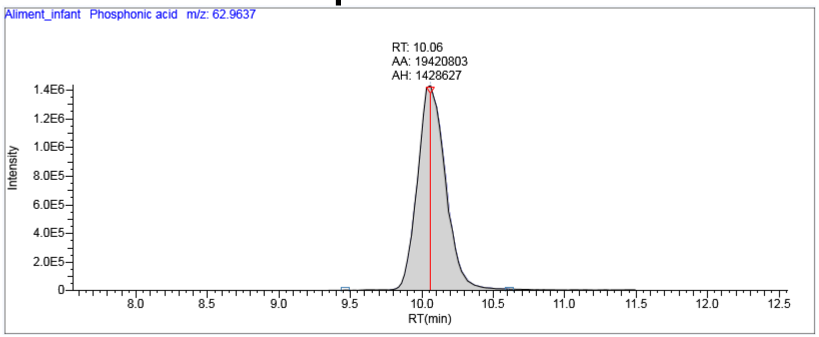
qualifier



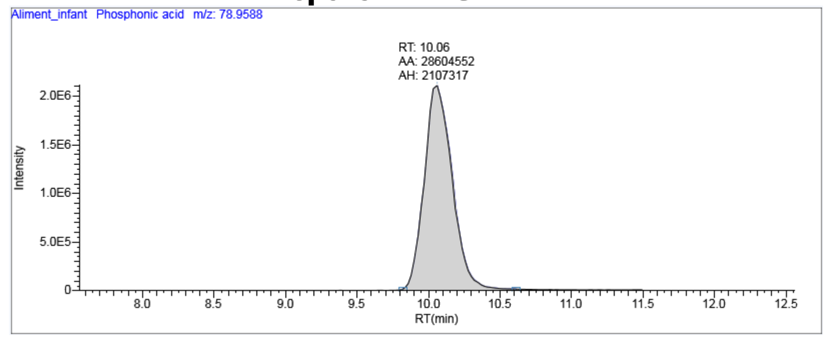
Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain ,

Baby food 0.26 mg/kg of phosphonic acid

quantifier

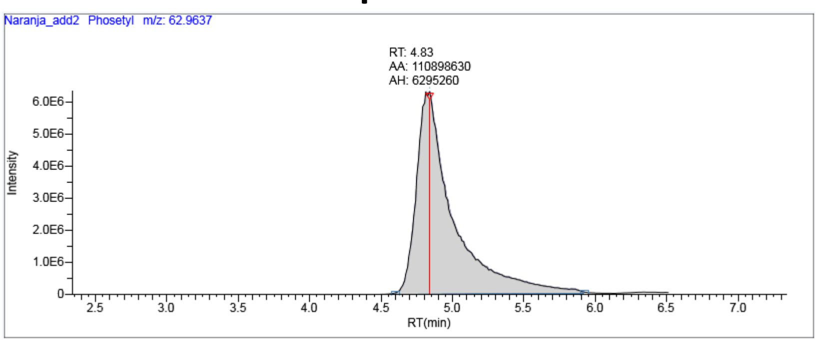


qualifier

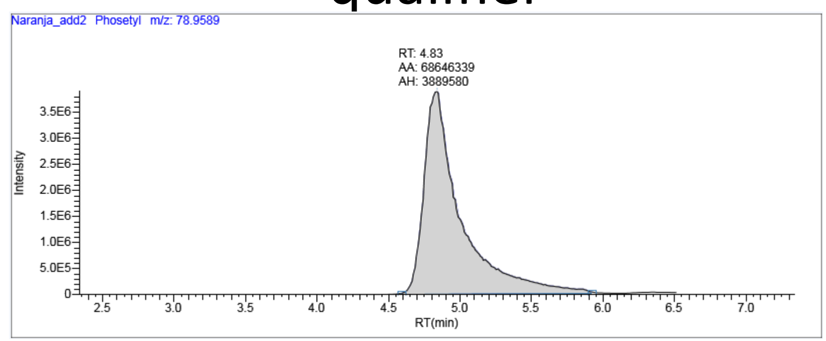


Orange 0.239 mg/kg of fosetyl-Al

quantifier



qualifier



Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain ,

Thermo Fisher SCIENTIFIC

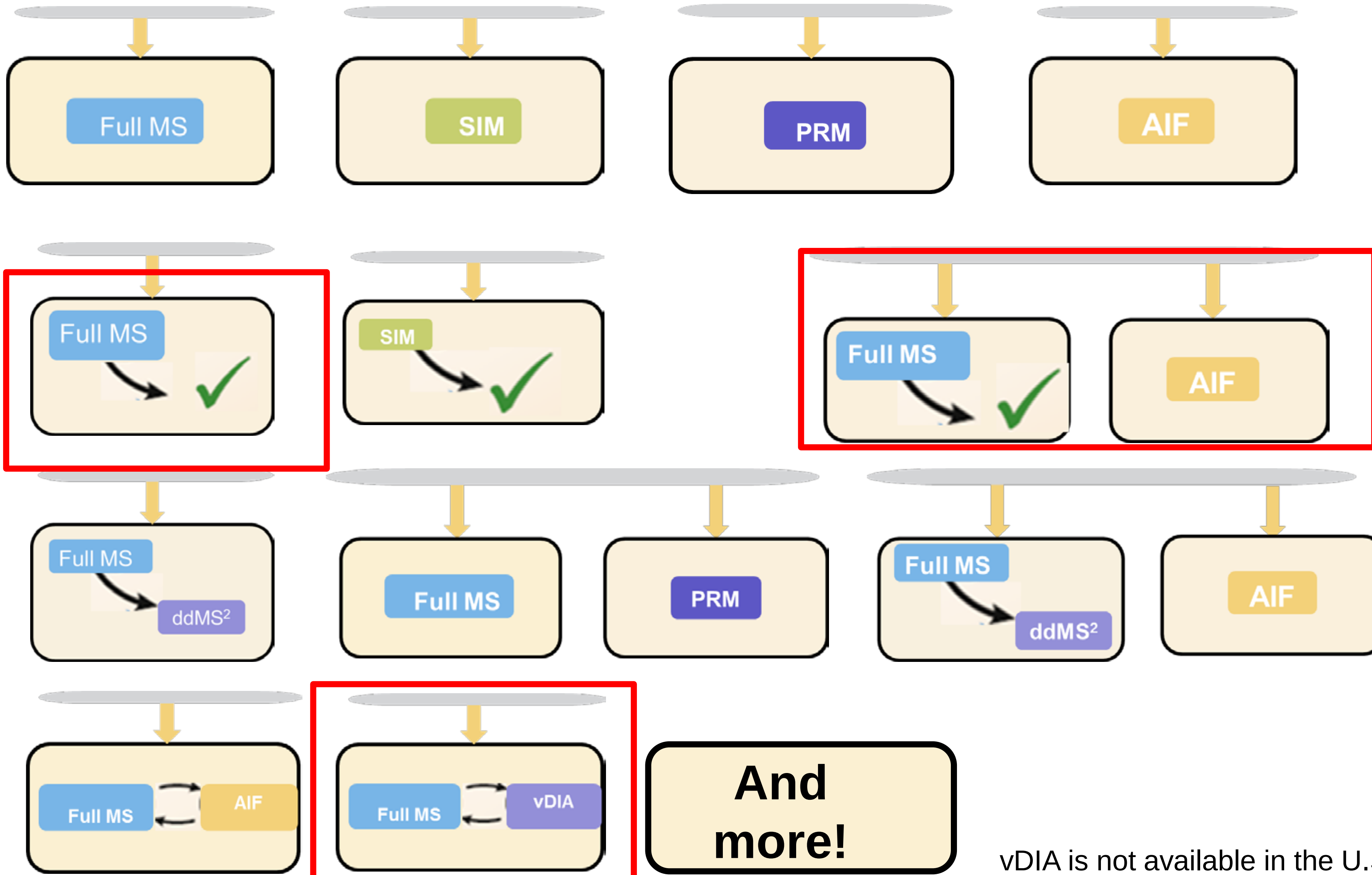
Q Exactive Focus hybrid quadrupole – Orbitrap MS

Q Exactive Focus Hybrid Quadrupole-Orbitrap MS

vDIA is not available in the U.S.

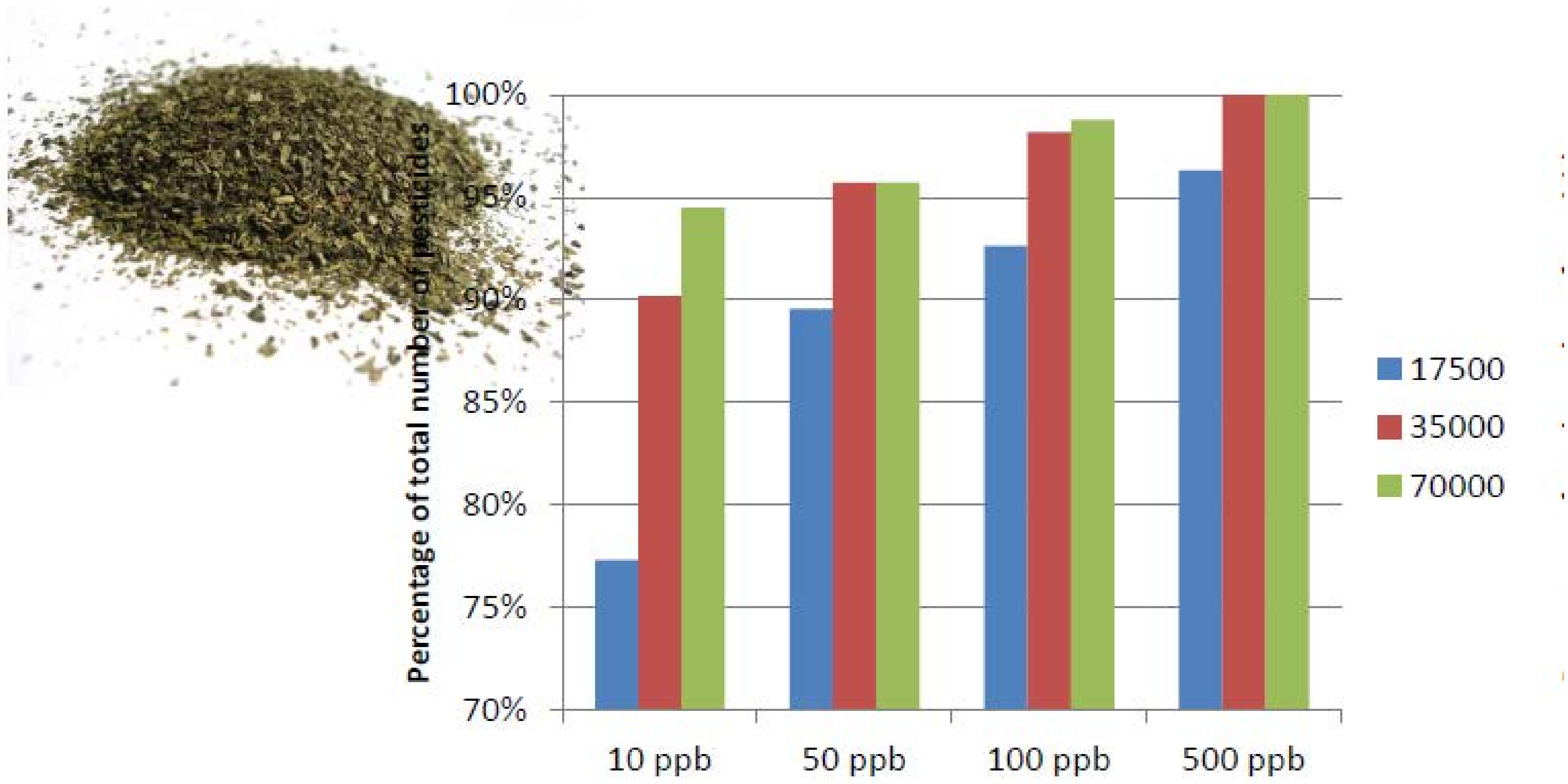
Mass Range	50 < *m/z* < 2,000
Resolution @ m/z 200	17,500 at 12 Hz 35,000 at 6 Hz 70,000 at 3 Hz
Top N	2
Mass Accuracy	< 1ppm RMS, Internal Calibration < 3ppm RMS, External Calibration
Polarity Switching	one full cycle –ve/+ve @ 35.000 RP in <1sec
Flexible Acquisition	Full scan dd-MS^2 AIF vDIA PRM (SIM)

Acquisition: Q Exactive Focus MS System



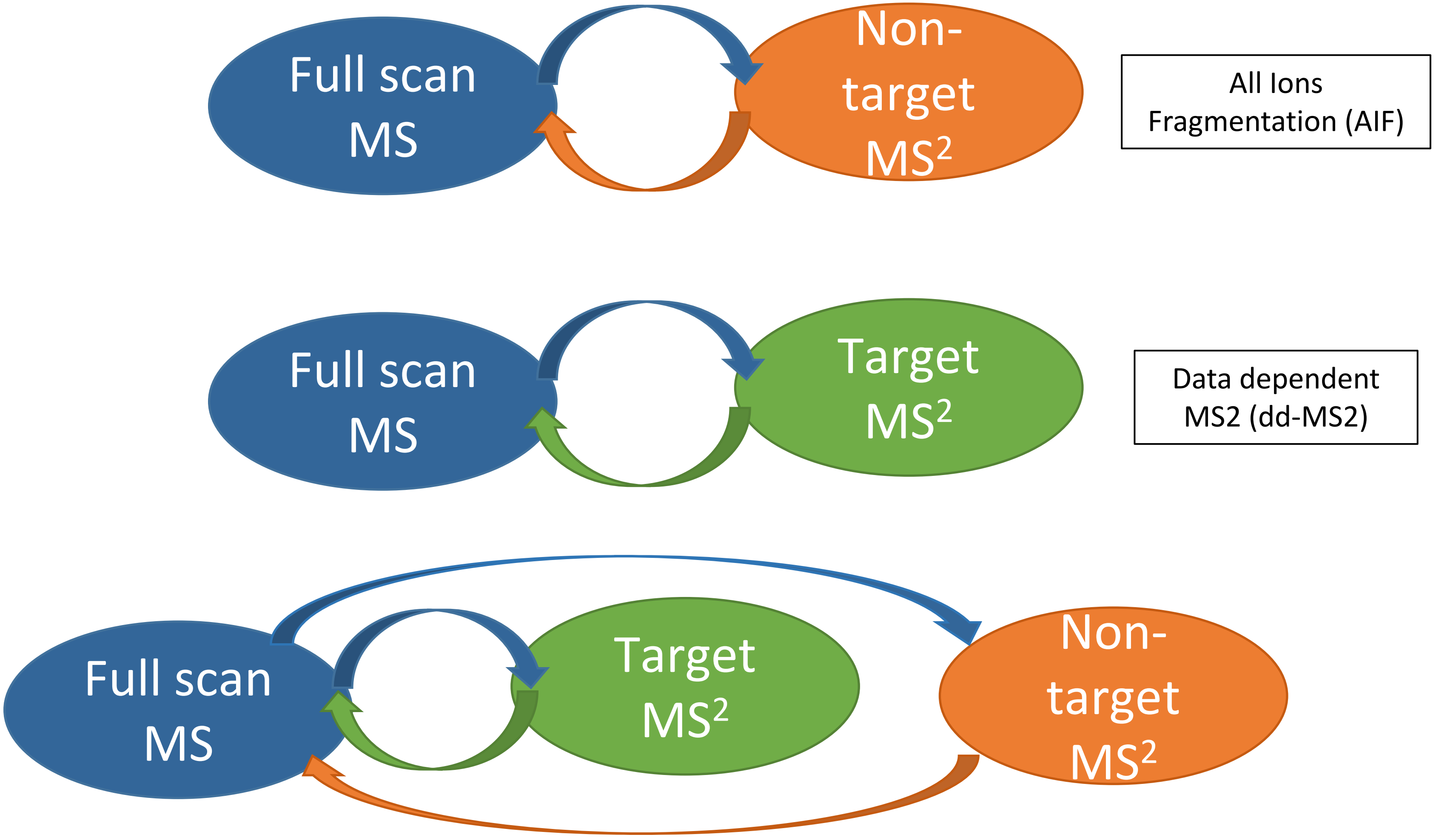
vDIA is not available in the U.S.

LC-HRAM - Does Resolving Power Matter?



Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain ,

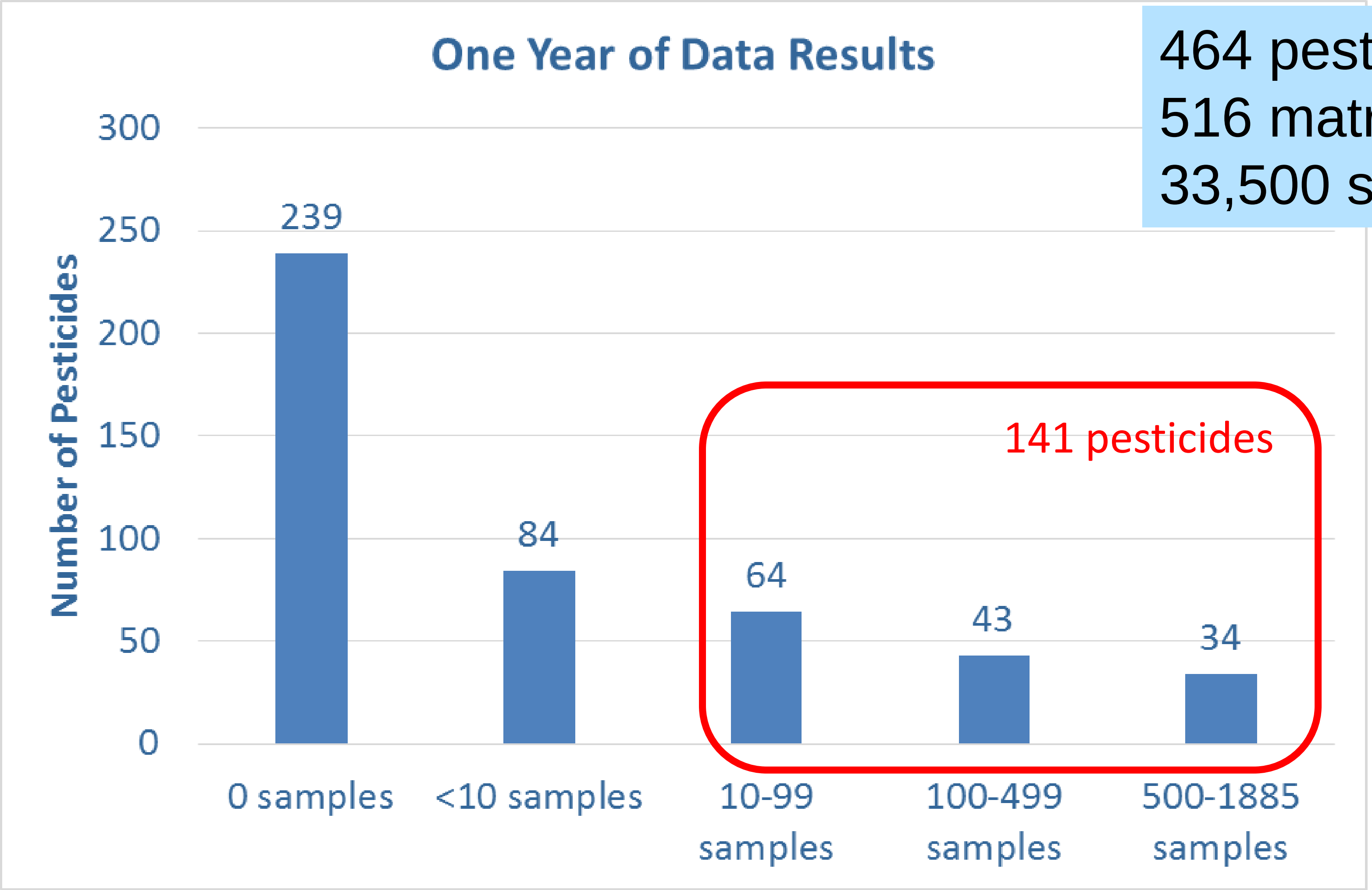
Possible Workflows in LC-Q-Orbitrap



FS/dd-MS²/AIF-MS²

Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain
,

Pesticides Detected in Routine



464 pesticides
516 matrices
33,500 samples

Data provided by eurofins | SiCA AgriQ

Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain ,

LC- Q Orbitrap Method

Target (166 compounds) FS-ddMS^2

Acephate	Emamectin B1a	Isoxaflutole	Propyzamide
Acetamiprid	Epoxiconazole	Kresoxim-methyl	Proquinazid
Aldicarb	Ethion	Linuron	Prothioconazole
Aldicarb-sulfone	Ethirimol	Lufenuron	Pymetrozine
Aldicarb-sulfoxide	Ethoprophos	Malaoxon	Pyraclostrobin
Azinphos-methyl	Etofenprox	Malathion	Pyrethrini
Azoxystrobin	Famoxadone	Mandipropamid	Pyrethrinii
Bifenazate	Fenamidone	Mepanipyrim	Pyridaben
Bitertanol	Fenamiphos	Metalaxyl	Pyridate
Boscalid	Fenamiphos-sulfone	Metconazole	Pyrimethanil
Bromuconazole	Fenamiphos-sulfoxide	Methidathion	Pyriproxyfen
Bupirimate	Fenarimol	Methiocarb	Quinoclamine
Buprofezin	Fenazaquin	Methiocarb-sulfone	Quinoxyfen
Carbaryl	Fenbuconazole	Methiocarb-sulfoxide	Rotenone
Carbendazim	Fenhexamid	Methomyl	Spinosyn A
Carbofuran	Fenoxycarb	Methoxyfenozide	Spinosyn D
Chlorantraniliprole	Fenpropathrin	Metobromuron	Spirodiclofen
Chlorfenvinphos, B-	Fenpropimorph	Monocrotophos	Spiromesifen
Chlorpyrifos	Fenpyrazamine	Myclobutanil	Spirotetramat
Chlorpyrifos-methyl	Fenpyroximate	Nitenpyram	Spiroxamine
Clofentezine	Fenthion	Omethoate	Tebuconazole
Clomazone	Fenthion-sulfone	Oxadixyl	Tebufenozide
Clothianidin	Fenthion-sulfoxide	Oxamyl	Tebufenpyrad
Coumaphos	Flonicamid	Paclobutrazol	Terbuthylazine
Cyazofamid	Flufenacet	Paraoxon methyl	Tetraconazole
Cymoxanil	Flufenoxuron	Penconazole	Thiabendazole
Cyproconazole	Fluopyram	Pencycuron	Thiacloprid
Cyprodinil	Fluquinconazole	Pendimethalin	Thiamethoxam
Cyromazine	Flusilazole	Phenthoate	Thiobencarb
Demeton-S-Methyl-Sulfone	Flutriafol	Phosalone	Thiodicarb
Demeton-S-methylsulfoxide	Formetanate	Phosmet	Thiophanate-methyl
Diazinon	Fosthiazate	Phoxim	Tolclofos-methyl
Dichlorvos	Haloxyfop	Pirimicarb	Triadimefon
Dicrotophos	Hexaconazole	Pirimicarb, desmethyl-	Triadimenol
Diethofencarb	Hexythiazox	Pirimiphos-methyl	Triazophos
Difenoconazole	Imazalil	Prochloraz	Trichlorfon
Diflubenzuron	Imidacloprid	Profenofos	Trifloxystrobin
Dimethoate	Indoxacarb	Propamocarb	Triflumuron
Dimethomorph	Iprovalicarb	Propaquizafop	Triticonazole
Diniconazole	Isocarbophos	Propargite	Zoxamide
Diuron	Isofenfos methyl	Propiconazole	
Dodine	Isoprocarb	Propoxur	

Non-target (102 compounds)-AIF-MS2

Acetochlor	Fenoxaprop-ethyl	Napropamide
Alachlor	Fenpropidin	Nuarimol
Ametryn	Fenuron	Ofurace
Anilofos	Flamprop-methyl	Oxycarboxin
Atrazine	Flazasulfuron	Paraoxon ethyl
Atrazine-Desethyl	Fluacrypyrim	Paraoxon methyl
Azamethiphos	Fluazifop-Butyl	Phosphamidon
Azinphos-ethyl	Fluometuron	Phosphamidon
Bensulfuron-methyl	Fluridone	Picolinafen
Bromacil	Fonofos	Picoxystrobin
Buturon	Forchlorfenuron	Promecarb
Cambendazole	Fuberidazole	Prometryn
Carbetamide	Furathiocarb	Propachlor
Chlorbromuron	Heptenophos	Propaphos
Chloridazon	Imazapyr	Propaquizafop
Chloroxuron	Imazaquin	Propazine
Chromafenozide	Isazofos	Prosulfocarb
Cinosulfuron	Isofenphos	Pyrazophos
Clethodim	Isofenphos-oxon	Pyridaphenthion
Cyanazine	Isoproturon	Pyrifenox
Diafenthiuron	Lenacil	Pyrimidifen
Dialifos	Mebendazole	Quinalphos
Diclobutrazol	Mecarbam	Sulfosulfuron
Difenoxuron	Metamitron	Sulprofos
Diflufenican	Metazachlor	Terbumeton
Dimefuron	Metolachlor	Terbuthylazine-desethyl
Dimethylvinphos, Z-	Metosulam	Tetrachlorvinphos
Dodemorph	Metoxuron	Thifensulfuron-methyl
Edifenphos	Metribuzin	Thiophanate
Ethiofencarb	Metsulfuron-methyl	Tolfenpyrad
Ethiprole	Mevinphos	Triasulfuron
Etrimfos	Monolinuron	Tribenuron-methyl
Fenbendazole	Monuron	Tricyclazole
Fenfuram	Naled	Vamidothion

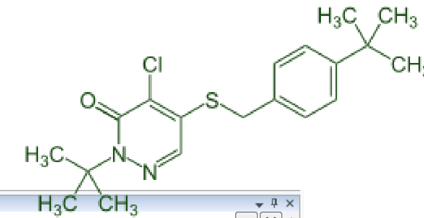
Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain ,

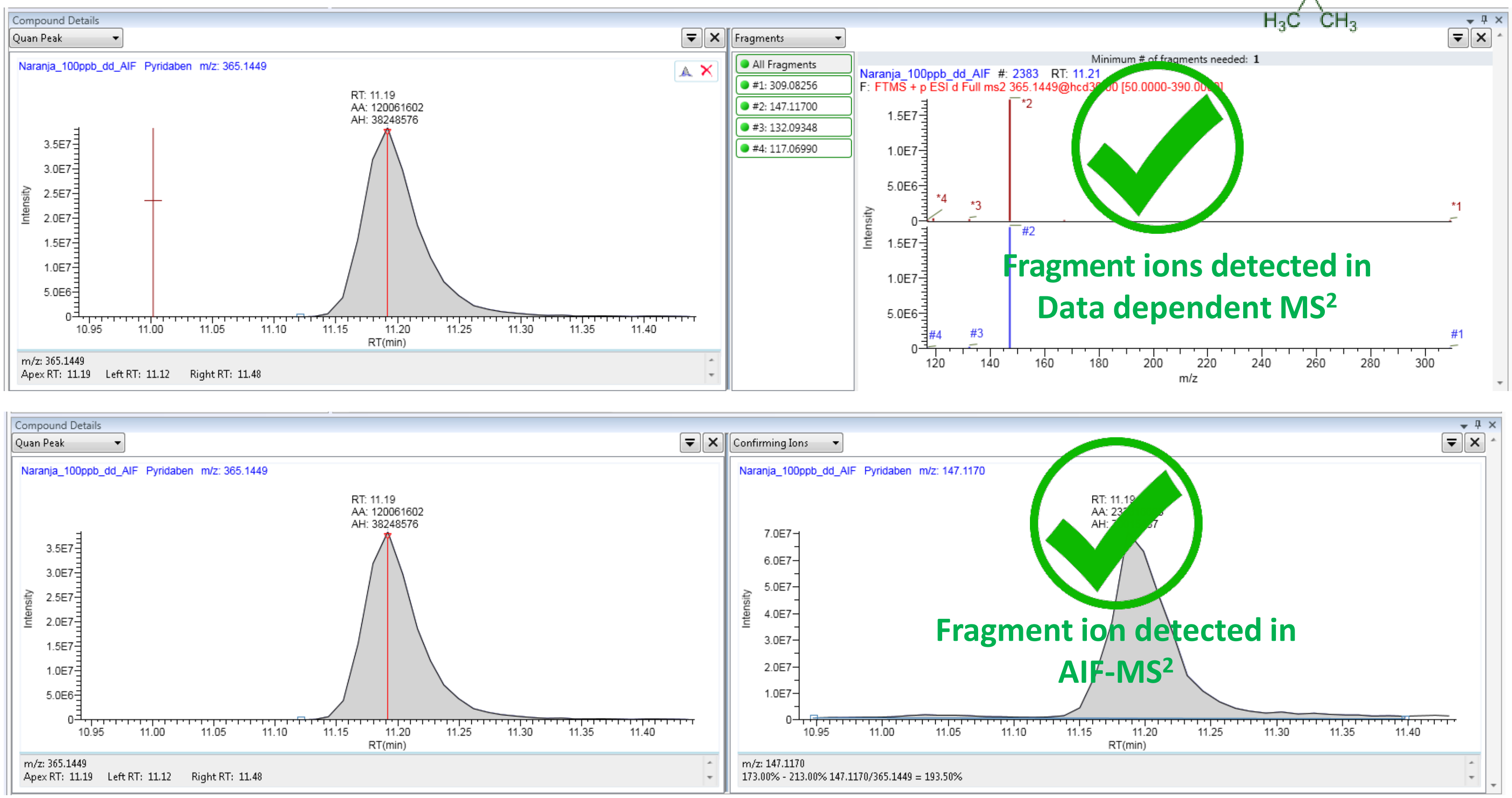
FS/dd-MS2/AIF-MS2

Pyridaben (target compound)
0.1 mg/kg in orange

MS

MS²

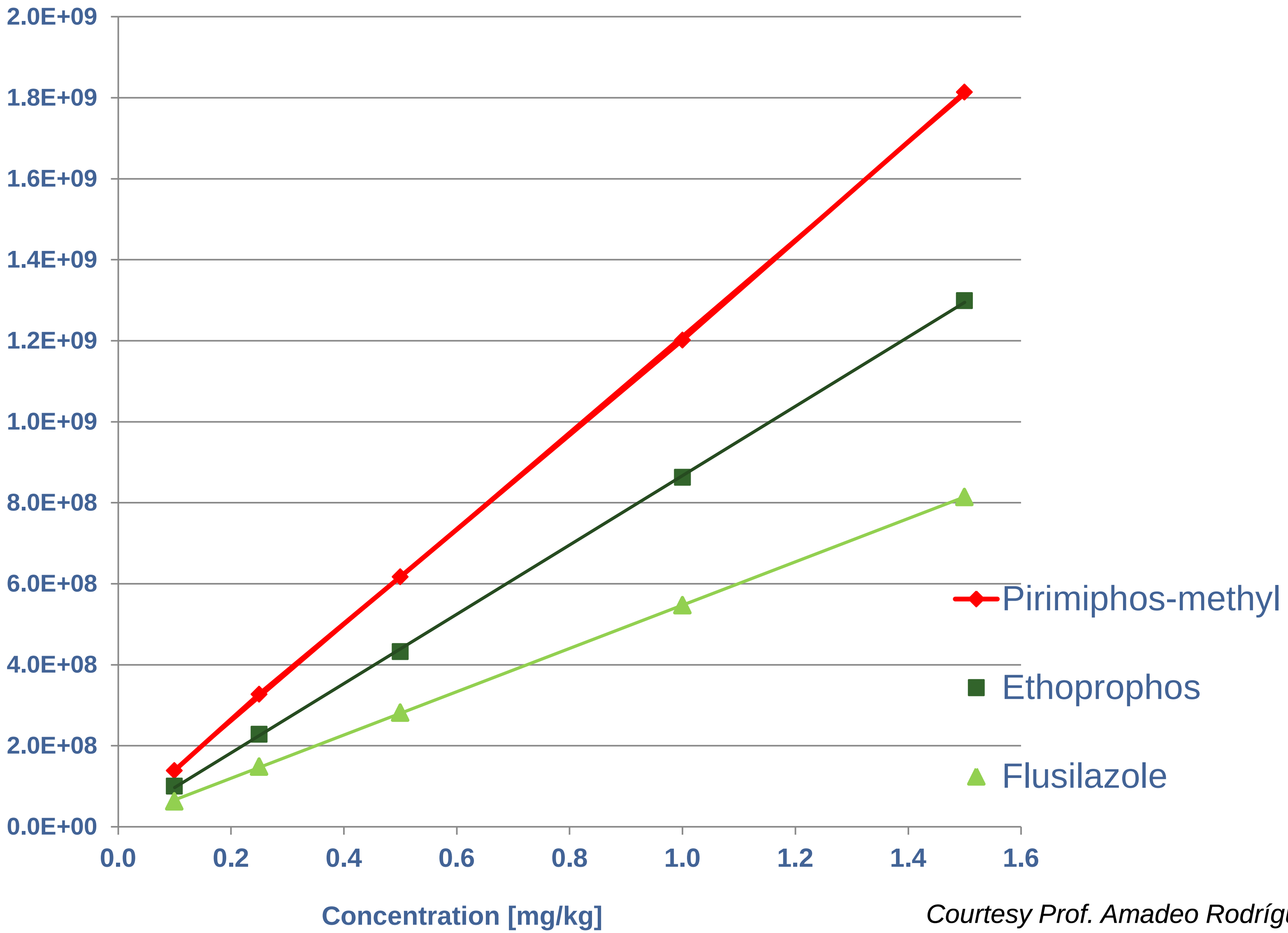




Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain

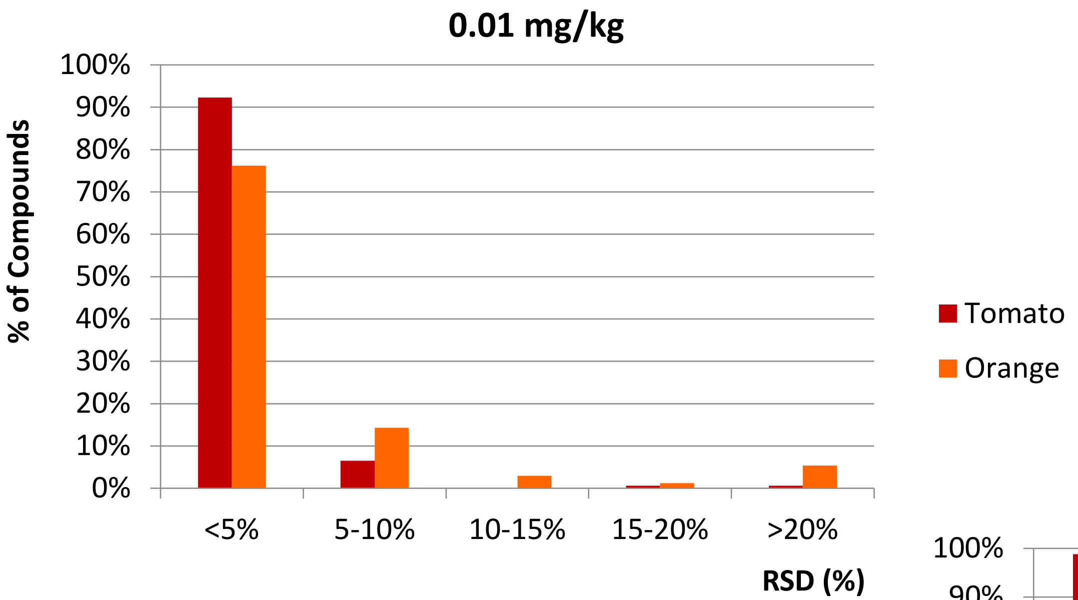
ThermoFisher SCIENTIFIC

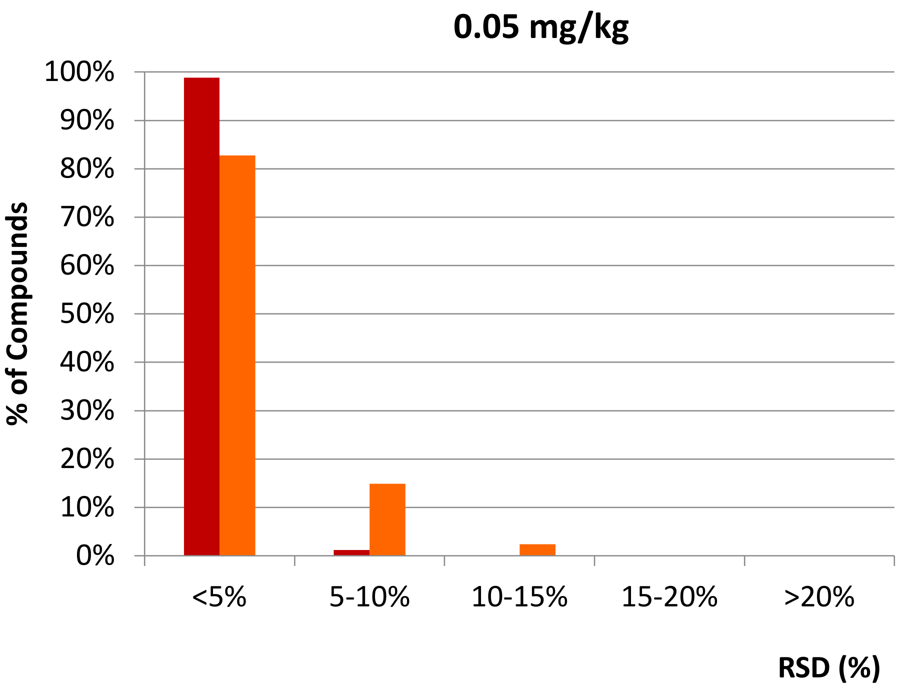
Validation: Linearity of Response in Spinach



Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain ,

Validation: Repeatability of Residue Concentrations





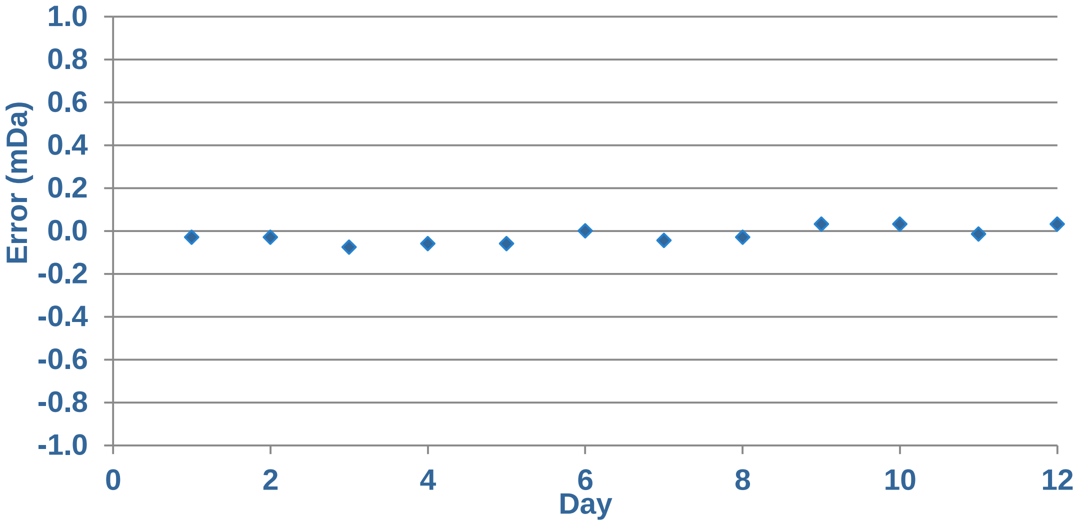
Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain

Analysis of Real Samples: Quantification

		Concentration (mg/kg)		
Matrix	Compound	LC-QqQ-MS/MS	LC-Q-Orbitrap-MS/MS	Diff (%)
Conferencia Pear1	Boscalid	0.168	0.154	8
	Difenoconazole	0.027	0.029	-7
	Diflubenzuron	0.014	0.017	-21
	Imazalil	1.711	1.334	22
	Imidacloprid	0.047	0.052	-11
	Pyraclostrobin	0.114	0.096	16
	Tebuconazole	0.048	0.048	0
	Thiacloprid	0.037	0.036	3
	Trifloxystrobin	0.024	0.021	13
Conferencia Pear2	Boscalid	0.175	0.177	-1
	Difenoconazole	0.012	0.013	-8
	Fluopyram	0.027	0.026	4
	Imazalil	1.359	1.093	20
	Imidacloprid	0.053	0.061	-15
	Pyraclostrobin	0.067	0.063	6
	Tebuconazole	0.044	0.047	-7
Red Pepper	Flutriafol	0.019	0.013	32
Red Chili Pepper	Flutriafol	0.397	0.368	7
	Pirimicarb	0.034	0.034	0
Banana	Imazalil	0.915	0.788	14

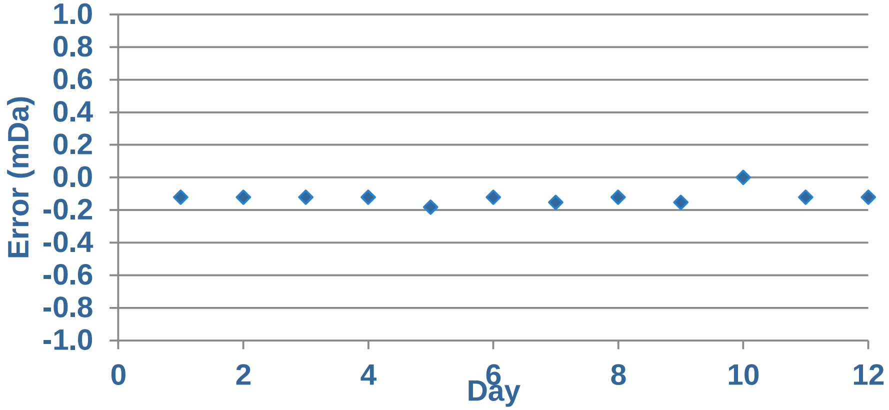
Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain

Validation of Method: Stability of Mass Accuracy



Carbendazim-d_3

Malathion-d_{10}

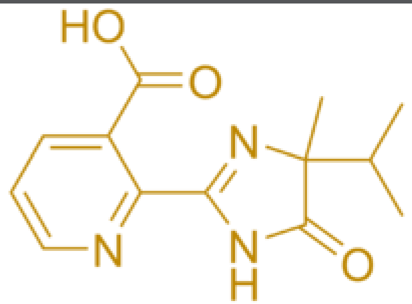


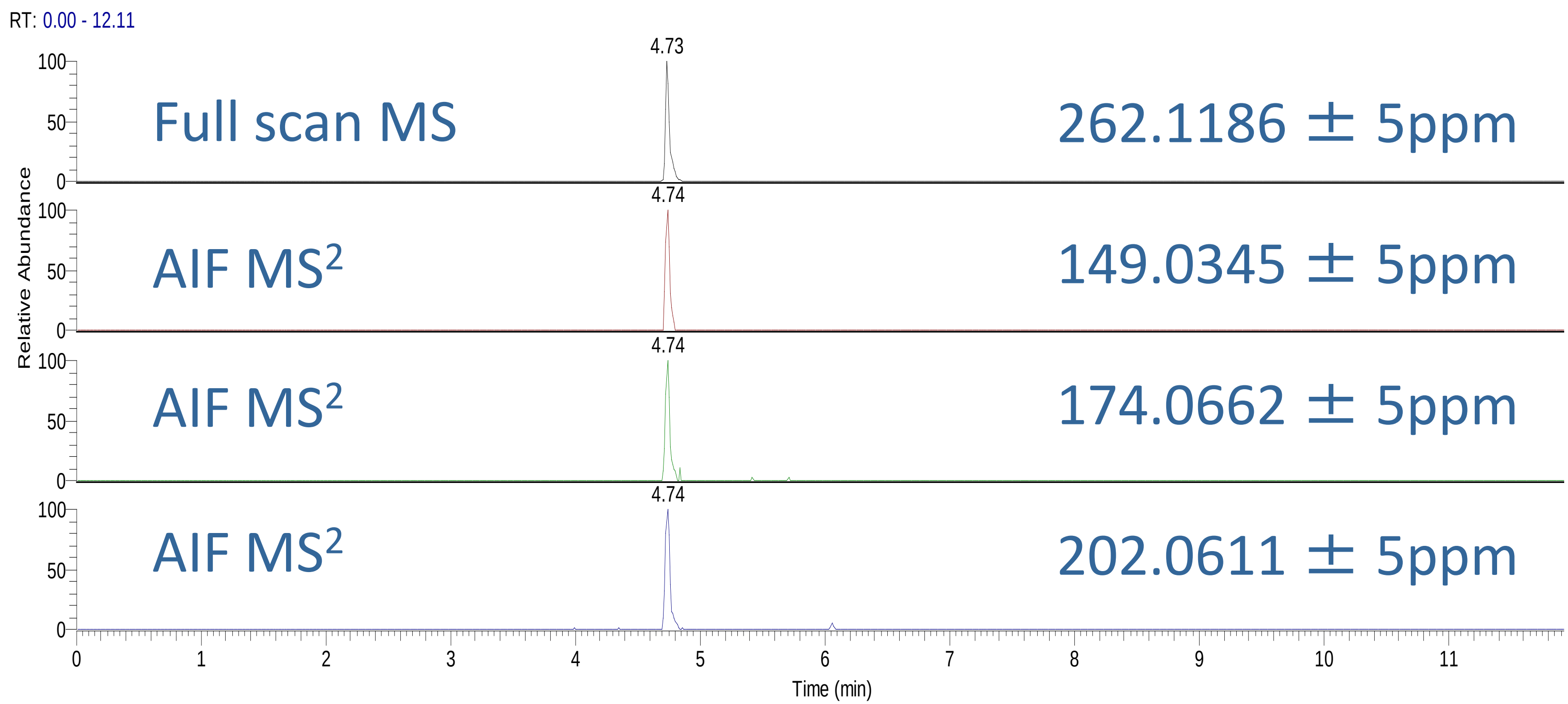
Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain

Analysis of Real Samples: Imazapyr in Pears

DETECTION OF NON-TARGET PESTICIDES

- not included in EU Monitoring Program
- protonated molecule = *m/z* 262.1186





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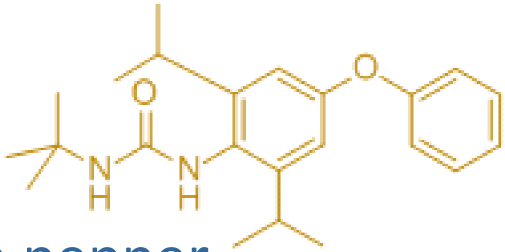
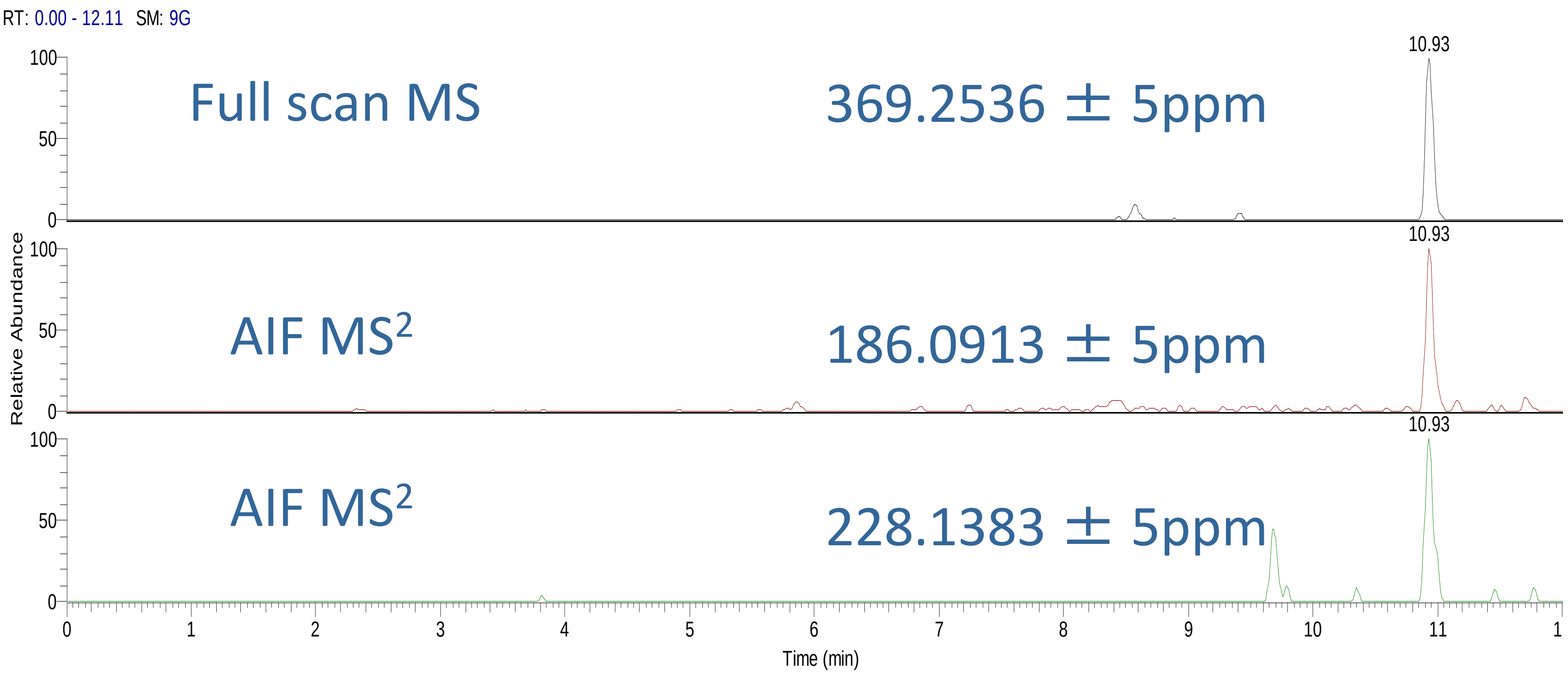
DETECTION OF NON-TARGET PESTICIDES



Diafenthiuron urea (metabolite of diafenthiuron) in pepper
mass of protonated molecule = *m/z* 369.2536



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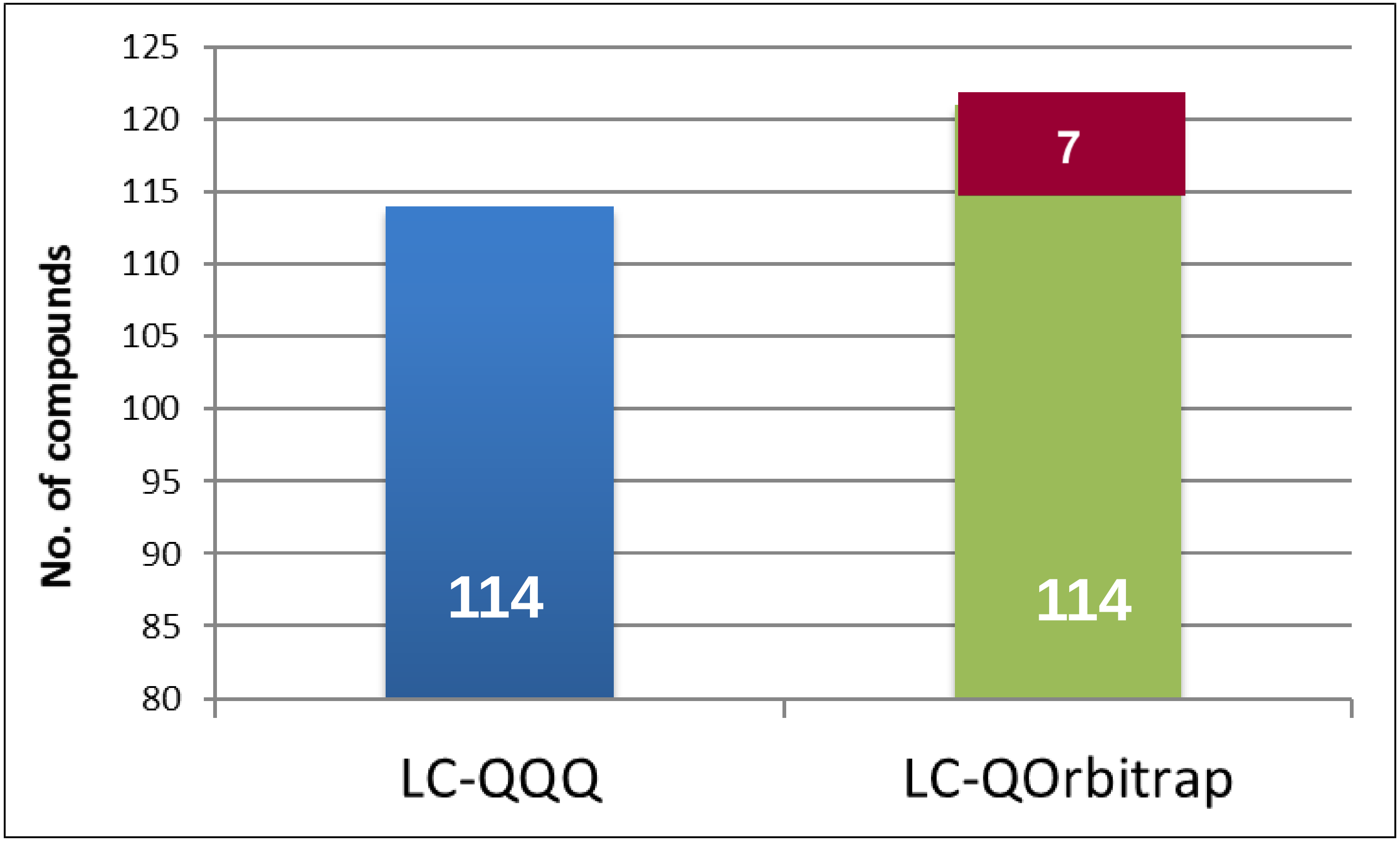
Analysis of Real Samples: Summary



7 additional pesticides not included in the scope of the LC-QQQ

Courtesy Prof. Amadeo Rodríguez Fernández-Alba, University of Almeria, Spain

Benefits from Utilization of Orbitrap MS technology

- Highest resolution and stable excellent mass accuracy at the low *m/z's* of interest
- Simultaneous targeted and non-targeted analysis in a single analysis
- Quantification of residues at least equal to triple quadrupole technology
- The highest selectivity for the accurate determination of residue concentrations in 'difficult' matrices
- 'Increased scope- acquiring all of the information all of the time'
- The possibility of retrospective analysis
- Proven robust instrumentation

- The benefits of ion chromatography: add a new capability to the workflow facilitating the migration of ionic pesticides into multi-residue method
- High capacity columns to cope with high matrix load to provide more resolution and retention time stability
- Robust columns and technology proven over 40 years of development

Thank You For Your Attention – Stay Connected with Us

Please join at our booth where we will address further comments and questions.

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