Pesticide Analysis in Food: Dispersive SPE (QuEChERS method)

Dr. Frank Michel
Pesticides in Food

Pesticides in
- fruit
- vegetable
- further food & feeding
Challenges in pesticide analysis:
Various different matrices

Fruit & vegetable
- Acidic/basic
- High/low water content
- High/low sugar content
- High/low starch or protein content
- High/low fat content
Herbs, tea, spices, honey, …
Pesticides in Agriculture

Annual use in EU: more than 200,000 tons of pesticides [1]
Amount of pesticides increased by factor of 50 since 1950 [2]
WHO classification of pesticides by hazard [3]

- Ia Extremely hazardous (28)
- Ib Highly hazardous (> 50)
- II Moderately hazardous (~ 200)
- III Slightly hazardous (~ 100)
- U Unlikely to present acute hazard

Full Variety of Pesticides …

- Amino acids: -5 to -1 (pH dependant)
- Sugars: -5 to -2
- Flavonoids/Anthocyanes: 0 to 6
- Fatty acids: 6 to 8.5
- Phytosterols: 8.5 to 11.5
- Acidic P. (~40): 3.8 to 8.3
- Pyrethroide-P. (~45): 3.5 to 7.0
- Organochlorine-P. (~20): -0.9 to 5.7
- Urea-P. (~30): 1.6 to 5.9
- Organophosphor-P. (~95): -0.9 to 5.7
- Carbamate-P. (~30): -0.4 to 5.5
- Basic P.: pH dependant
- Phthalate: 2.5 to 6
- PAHs: 3.3 to 6.8
- PBDEs: 6.2 to 9.5
- PCBs: 5 to 8.5
- Glyphosate: -4
- Streptomycin: -7.5
- Quat-P.: -4.5 to -2.8
- Vit. E: 11.5
- Carotenoides: 11 to 18
- Chlorophyll: 17.2

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Full Variety of Pesticides …

- Amino acids
  - pH dependant
- Sugars
  - pH dependant
- Acetic acid
- Propionic acid
- Butyric acid
- Valeric acid
- Caproic acid
- Decanoic Acid
- Palmitic acid
- Stearic acid
- Linoleic acid
- Linolenic acid
- Fatty acids
- Flavonoids/Anthocyanes
- Basic P.
  - pH dependant
- Acidic P.
  - pH dependant
- Phthalate
  - 2.5 – 6
- Polybrominated Diphenyl Ethers (PBDEs)
  - 6.2 – 9.5
- Polyaromatic Hydrocarbons (PAHs)
  - 3.3 – 6.8
- Phenanthrene (PAHs)
  - 3.7 – 6.2
- Pyrene (PAHs)
  - 4.1 – 6.7
- Fluoranthene (PAHs)
  - 3.8 – 6.9
- Benzo(a)anthracene (PAHs)
  - 4.1 – 6.7
- Benzo(b)fluoranthene (PAHs)
  - 3.8 – 6.9
- Benzo(k)fluoranthene (PAHs)
  - 3.8 – 6.9
- Benzo(a)pyrene (PAHs)
  - 3.8 – 6.9
- Chrysene (PAHs)
  - 3.8 – 6.9
- Benzo(e)pyrene (PAHs)
  - 3.8 – 6.9
- Benzo(g,h,i)perylene (PAHs)
  - 3.8 – 6.9
- Anthracene (PAHs)
  - 3.8 – 6.9
- Phenanthrene (PAHs)
  - 3.7 – 6.2
- Fluoranthene (PAHs)
  - 3.8 – 6.9
- Dieldrin (Organochlorine-P.)
  - 3.5 – 7.0
- Aldrin (Organochlorine-P.)
  - 1.6 – 5.9
- DDT (Organochlorine-P.)
  - 1.6 – 5.9
- Dichlorodiphenyltrichloroethane (DDE)
  - 1.6 – 5.9
- Chlordane (Organochlorine-P.)
  - 1.6 – 5.9
- Heptachlor (Organochlorine-P.)
  - 1.6 – 5.9
- Lindane (Organochlorine-P.)
  - 1.6 – 5.9
- Pyrethrol (Organochlorine-P.)
  - 1.6 – 5.9
- Pyrethrin (Organochlorine-P.)
  - 1.6 – 5.9
- Phenol (Organochlorine-P.)
  - 1.6 – 5.9
- Ozone (Organochlorine-P.)
  - 1.6 – 5.9
- Terbuthylazine (Organochlorine-P.)
  - 1.6 – 5.9
- Terbutylazine (Organochlorine-P.)
  - 1.6 – 5.9
- Endosulfan I (Organochlorine-P.)
  - 1.6 – 5.9
- Endosulfan II (Organochlorine-P.)
  - 1.6 – 5.9
- Endrin (Organochlorine-P.)
  - 1.6 – 5.9
- Heptachlor (Organochlorine-P.)
  - 1.6 – 5.9
- Dieldrin (Organochlorine-P.)
  - 1.6 – 5.9
- Aldrin (Organochlorine-P.)
  - 1.6 – 5.9
- DDT (Organochlorine-P.)
  - 1.6 – 5.9
- Chlorinated Paraffins (Organochlorine-P.)
  - 1.6 – 5.9
- Polychlorinated Biphenyls (PCBs)
  - 3.3 – 6.8
- TEA (PCBs)
  - 3.7 – 6.3
- Co (PCBs)
  - 3.7 – 6.3
- TC (PCBs)
  - 3.7 – 6.3
- Aroclor 1260 (PCBs)
  - 3.7 – 6.3
- Aroclor 1242 (PCBs)
  - 3.7 – 6.3
- Aroclor 1254 (PCBs)
  - 3.7 – 6.3
- Aroclor 1268 (PCBs)
  - 3.7 – 6.3
- Phthalate (Phthalate)
  - 2.5 – 6
- PBDEs (PBDEs)
  - 6.2 – 9.5
- PAHs (PAHs)
  - 3.3 – 6.8
- PCBs (PCBs)
  - 5 – 8.5

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Pesticides in fruit & vegetable – former methods

- Homogenization
- Extraction
- Purification
- Gas chromatography
Pesticides in fruit & vegetable – former methods

10 years ago .... Liquid Extraction with dichloromethane followed by gel chromatography and fractionation by silica SPE
Pesticides in fruit & vegetable – former methods

From 2004:

Accelerated Solvent Extraction (ASE, e.g. Dionex)  Gel chromatography

GC/MS Analysis

Additional work-up for LC-MS/MS
Full Variety of Pesticides …

- Amino acids
  - pH dependant
- Sugars
  - pH dependant
- Streptomycin
  - pH dependant
- Glyphosate
- Quat-P.
  - pH dependant
- Basic P.
  - pH dependant
- Acidic P.
  - pH dependant
  - GC only after Derivatization
- Pyrethroid-P.
  - (~45) GPC
- Organochlorine-P.
  - (~20) GPC
- Organophosphor-P.
  - (~95) GPC
- Carbamate-P.
  - (~30) GPC
- GPC/Silica
- PAHs
  - 3.3 – 6.8
- GPC
- PBDEs
  - 6.2 – 9.5
- Phthalate
  - 2.5 – 6
- GC
  - Phytosterols
  - 8.5 – 11.5
- GPC
- Flavonoids/Anthocyanes
  - 0 – 6
- Fatty acids
  - 6 – 8.5
- GPC
- GC
  - 11.5
- Carotenoids
  - 11 – 18
- Chlorophyll
  - 17 – 21
- Vit. E
  - 11.5
- GPC
  - Silica
- Sugars
  - -5 – -2
- Amino acids
  - -5 – -1 (pH dependant)
- Fatty acids
  - 6 – 8.5
- Carotenoids
  - 11 – 18
- Chlorophyll
  - 17.2
- Vit. E
  - 11.5
- Sugars
  - -5 – -2
- Flavonoids/Anthocyanes
  - 0 – 6
- GPC
QuEChERS Method: dispersive SPE

Quick
Easy
Cheap
Effective
Rugged
Safe

M. Anastassiades, S. Lehotay et al., J. AOAC Int. 86 (2) 412-431, 2003

LCGC North America, Jul 1, 2010
How does the QuEChERS method work?

Homogenize

Frozen Samples

Addition of solid CO₂
How does the QuEChERS method work?

Weigh in 10 g sample into a 50 mL centrifuge tube with screw cap

Shake 1 min virigously

Add 10 mL Acetonitrile & 100 µL Internal Standard

(* for samples with high fat content IS should be added after phase separation)
How does the QuEChERS method work?

Add magnesium sulfate, and buffer salt

EN Buffer:
Trisodium citrat dihydrate; disodium hydrogencitrate sesquihydrate, sodium chloride

AOAC Buffer:
Na Acetate

Important: First sample in the vial then add salts to prevent lumping of salts. Shake immediately.
How does the QuEChERS method work?

- 5 min centrifugation
- If needed: take 1 ml raw extract for acidic pesticides

- Acetonitrile phase (to be used for further analysis)
- Organic Precipitate
- Water from the sample
- Salts
How does the QuEChERS method work?

Transfer acetonitrile phase to a centrifuge tube with magnesium sulfate and PSA (Primary Secondary Amine). 25 mg PSA + 150 mg MgSO₄ per mL extract.

Requirements for colored or fat-containing samples:
Add GCB for heavily pigmented samples. Add C18, Z-Sep/C18 or Z-Sep+ for lipid containing samples.
QuEChERS Method:
Sample Clean-up based around PSA adsorbent

PSA - Primary Secondary Amine

- two $\text{pK}_a$ [10.1 and 10.9]

- Better interaction due to two $\text{pK}_a$ values

Removal of

- fatty acids
- organic acids
- polar pigments
- sugars

Also available in tubes
How does the QuEChERS method work?

5 min centrifugation

Use the clear supernatant for chromatography

Acidify with 5% formic acid to pH 5
How does the QuEChERS method work?

1. Weigh in 10 g sample
2. Add 10 mL Acetonitrile
3. Add Internal Standard
   - Shake
4. Add 4 g MgSO₄ and 1 g NaCl, adjust to pH 5 - 5.5 with citrate buffer
   - Shake & centrifuge
5. Add MgSO₄ and PSA/(GCB) to aliquot
   - Shake & centrifuge
6. Acidify extract to pH ~ 5
7. GC-MSD and LC-MSMS

Option: Acidic pesticides LC-MSMS
Option: Acid labile pesticides LC-MSMS
QuEChERS method: issues to consider

- Homogenization with dry ice
- Extraction: pH adjustment to 5 – 5,5 (add NaOH, if needed)
- Aliquot for acidic pesticides before PSA addition
- GCB for coloured samples (chlorophyll, carotenoids)
- C18, Z-Sep/C18 or Z-Sep+ for lipid containing samples
- Aliquot for acid labile pesticides before acidification
- Acidification of purified extract to pH = 5
- For GC: use of a PTV (and automated liner exchange)

- Samples with low water content (< 80 %) e.g. grain, honey, tea, herbs, spices and dried fruit
# Samples with low water content

<table>
<thead>
<tr>
<th>Sample type</th>
<th>Weight</th>
<th>Water</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>5 g</td>
<td>10 g</td>
<td></td>
</tr>
<tr>
<td>Dried fruits</td>
<td>5 g</td>
<td>7.5 g</td>
<td>Water can be added during comminution step. 12.5 g homogenate is used for analysis</td>
</tr>
<tr>
<td>Fruits and vegetables, &gt; 80 % water content</td>
<td>10 g</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Fruits and vegetables, 25-80 % water content</td>
<td>10 g</td>
<td>X g</td>
<td>X = 10 g – water amount in 10 g sample</td>
</tr>
<tr>
<td>Honey</td>
<td>5 g</td>
<td>10 g</td>
<td></td>
</tr>
<tr>
<td>Spices</td>
<td>2 g</td>
<td>10 g</td>
<td></td>
</tr>
</tbody>
</table>
QuEChERS Method:
Sample Clean-up for pigmented or fat-rich samples

Pigmented samples:
• ENVI-Carb selectively removes chlorophyll and carotenoids

Fat-containing samples:
• Freezing out of the fat
• C18 SPE adsorbent removes the fat
• Supel QuE Z-Sep/C18 (Discovery® DSC-18 + Z-Sep) for samples containing <15% fat
• Supel QuE Z-Sep+ (C18 and zirconia dual bonded to silica) for samples containing >15% fat
Literature values for extraction of problematic pesticides from fatty matrices (more than 5% fat)

<table>
<thead>
<tr>
<th>Matrix</th>
<th>Cleanup used</th>
<th>Hexachlorobenzene</th>
<th>Endosulfan</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avocado</td>
<td>QuEChERS, PSA/C18</td>
<td>27%</td>
<td>90%</td>
<td>Lehotay &amp; Mastovska 2005</td>
</tr>
<tr>
<td>Avocado</td>
<td>GPC, extraction using ethyl acetate-cyclohexane</td>
<td>-</td>
<td>78%</td>
<td>J.L.F. Moreno et al, 2006</td>
</tr>
<tr>
<td>Dough</td>
<td>QuEChERS, PSA/C18</td>
<td>52%</td>
<td>112%</td>
<td>U. Koesukwiwat et al., 2010</td>
</tr>
<tr>
<td>Dough</td>
<td></td>
<td>25%</td>
<td>73%</td>
<td></td>
</tr>
</tbody>
</table>
What are Supel QuE Z-Sep/C18 and Z-Sep+?

The Zr atom on the particle acts as a Lewis acid.

The phosphate groups on the phospholipids are strong Lewis bases and complex with the zirconium atoms.

Analytes are free of phospholipids (diminishes fatty matrix interferences).

Removes various colors, specifically green pigments.

Proprietary HybridSPE zirconia-coated silica

Phospholipids

The Zr atom acts as a Lewis acid (electron acceptor) because it has empty d-orbitals.
Supel QuE Z-Sep/C18 and Z-Sep+

- **Z-Sep/C18 Sorbent:** A mixture of **Z-Sep** (proprietary zirconia-coated silica particles) and **Discovery DSC-18**
- **Useful for fatty matrices containing <15% fat**

- **Z-Sep+ Sorbent:** Proprietary dual bonded **C18** and **zirconia** on silica
- **Useful for the analysis of fatty matrices containing >15% fat**
Comparison of sorbents for retention of model fatty compounds – oleins.

25 mg of sorbent mixed with 1 mL of olein solution in acetonitrile (400mg/mL total concentration).

The remaining oleins were quantified by LC-ELSD and retention was calculated.
Pesticides in olives

- 38 pesticides tested in canned olives
- Selected results are shown in the Figure

- Recoveries for most pesticides are similar between 2 methods
- Better recoveries for some pesticides observed using Z-Sep/C18
  - Fenhexamide (no ion suppression for Z-Sep/C18)
  - Anilazine (no ion suppression for Z-Sep/C18)
  - Sethoxydim (no ion suppression for Z-Sep/C18)
QuEChERS: Pesticides in avocado by GC-MS

- Pesticide mix included hydrophobic compounds (e.g. organochlorines, hexachlorobenzene) and some other more polar classes all GC-MS amenable
- QuEChERS extraction was performed
  - Ratio 3 g sample to 25 mL acetonitrile extraction solvent improved recoveries
  - Tested cleanup used Z-Sep+ with and without PSA and C18

Extraction and Cleanup Procedures

1. Place 3 g of a homogenized avocado sample into a 50 mL centrifuge tube (Cat. No. 55248-U). Add spike solution if a spiked replicate.
2. Add 25 mL of acetonitrile (Cat. No. 34481), and shake for one minute.
3. Add the contents of an Acetate Extraction Tube (Cat. No. 55234-U), and shake for one minute.
4. Centrifuge for five minutes.
5. Transfer 3 mL of the supernatant into the appropriate cleanup tube, Z-Sep+ (Cat. No. 55296-U) or PSA/C18 (Cat. No. 55229-U).
6. Shake for one minute, then centrifuge for three minutes.
7. Transfer 1 mL of the supernatant into an autosampler vial for GC-MS analysis.
QuEChERS: Pesticides in avocado by GC-MS

Results: Pesticide Recovery

- Z-Sep+ showed better recovery overall.
- PSA/C18: matrix interference prevented analysis of cyfluthrin, cypermethrin and deltametrin.
- Z-Sep+ showed better reproducibility than PSA/C18.
**QuEChERS method: EU and US**

**EN 15662:2008** “Foods of plant origin – Determination of pesticide residues using GC-MS and/or LC-MS/MS following acetonitrile extraction/partitioning and cleanup by dispersive SPE – QuEChERS-method”

**AOAC Official Method 2007.01** “Pesticide Residues in Foods by Acetonitrile Extraction and Partitioning with Magnesium Sulfate”.

**LCGC North America, Jul 1, 2010**
<table>
<thead>
<tr>
<th>Wirkstoffe mit allgemein guter Wiederfindung und Präzision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bendiocarb 98% 100% 104% 100% 98% 101% 101% 98% 5% 7% 4% 7% 3% 4% 3%</td>
</tr>
<tr>
<td>Butocarboxim 89% 81% 97% 81% 96% 97% 96% 96% 20% 47% 5% 47% 6% 13% 4%</td>
</tr>
<tr>
<td>Carbofuran 101% 98% 101% 98% 97% 104% 98% 98% 4% 6% 13% 6% 3% 12% 5%</td>
</tr>
<tr>
<td>Cyprodinil 99% 97% 97% 97% 97% 94% 97% 97% 9% 9% 3% 9% 6% 2% 4%</td>
</tr>
<tr>
<td>Dimethoat 102% 100% 98% 100% 98% 99% 94% 93% 4% 4% 4% 4% 1% 2% 5%</td>
</tr>
<tr>
<td>Fenhexamid 81% 83% 99% 83% 92% 77% 91% 83% 17% 16% 3% 16% 17% 14% 3%</td>
</tr>
<tr>
<td>Fenoxycarb 101% 98% 104% 98% 96% 102% 104% 4% 8% 8% 8% 5% 8% 3% 4%</td>
</tr>
<tr>
<td>Fenthion 99% 97% 97% 97% 97% 94% 97% 97% 9% 9% 3% 9% 6% 2% 4%</td>
</tr>
<tr>
<td>Imazalil 80% 82% 82% 82% 81% 82% 82% 82% 32% 19% 3% 19% 3% 18% 11%</td>
</tr>
<tr>
<td>Isoproturon 97% 96% 98% 96% 96% 97% 98% 99% 4% 6% 13% 6% 3% 18% 6%</td>
</tr>
<tr>
<td>Linuron 100% 98% 99% 98% 98% 104% 98% 98% 4% 6% 13% 6% 3% 18% 6%</td>
</tr>
<tr>
<td>Metolachlor 101% 98% 104% 98% 96% 102% 104% 4% 8% 8% 8% 5% 8% 3% 4%</td>
</tr>
<tr>
<td>Monocrotophos 96% 95% 95% 95% 95% 95% 95% 95% 4% 8% 8% 8% 5% 8% 3%</td>
</tr>
<tr>
<td>Oxamyl 100% 98% 104% 98% 96% 102% 104% 4% 8% 8% 8% 5% 8% 3% 4%</td>
</tr>
<tr>
<td>Picoxystrobin 100% 98% 104% 98% 96% 102% 104% 4% 8% 8% 8% 5% 8% 3% 4%</td>
</tr>
<tr>
<td>Pirimicarb 92% 93% 96% 93% 96% 93% 96% 93% 4% 8% 8% 8% 5% 8% 3% 4%</td>
</tr>
<tr>
<td>Promecarb 99% 96% 96% 96% 96% 96% 96% 96% 4% 8% 8% 8% 5% 8% 3% 4%</td>
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<tr>
<td>Propamocarb 94% 94% 94% 94% 94% 94% 94% 94% 4% 8% 8% 8% 5% 8% 3% 4%</td>
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<tr>
<td>Pyridostrobin 99% 99% 99% 99% 99% 99% 99% 99% 4% 8% 8% 8% 5% 8% 3% 4%</td>
</tr>
<tr>
<td>Selenium 90% 92% 96% 92% 96% 92% 96% 92% 4% 8% 8% 8% 5% 8% 3% 4%</td>
</tr>
<tr>
<td>Ethiofencarb 90% 92% 96% 92% 96% 92% 96% 92% 4% 8% 8% 8% 5% 8% 3% 4%</td>
</tr>
<tr>
<td>Metsulfuron-methyl 63% 64% 69% 64% 64% 64% 64% 64% 29% 30% 16% 30% 70% 100% 45%</td>
</tr>
<tr>
<td>Prosulfuron 71% 69% 76% 69% 69% 69% 69% 69% 27% 23% 8% 23% 50% 60% 52%</td>
</tr>
<tr>
<td>Tebuconazole 103% 101% 98% 101% 98% 100% 100% 100% 4% 5% 4% 5% 2% 5% 4%</td>
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<tr>
<td>Tebufenozid 103% 101% 98% 101% 98% 100% 100% 100% 4% 5% 4% 5% 2% 5% 4%</td>
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<tr>
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<tr>
<td>Thiaendiol 54% 59% 91% 95% 88% 91% 86% 84% 27% 23% 8% 23% 50% 60% 52%</td>
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<tr>
<td>Thioclidxid 101% 95% 93% 95% 93% 93% 93% 93% 5% 6% 11% 6% 5% 8% 5%</td>
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<tr>
<td>Thiobencarb 103% 101% 98% 101% 98% 100% 100% 100% 4% 5% 4% 5% 2% 5% 4%</td>
</tr>
<tr>
<td>Vamidothion 98% 96% 98% 96% 96% 96% 96% 93% 91% 5% 6% 10% 6% 5% 4% 9%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sulfonyl urea compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethion 61% 61% 91% 91% 91% 91% 85% 90% 45% 29% 5% 29% 5% 29% 5% 29% 5% 29% 5% 29% 5%</td>
</tr>
<tr>
<td>Metolachlor 83% 64% 99% 99% 99% 99% 81% 84% 74% 84% 10% 10% 10% 10% 10% 10%</td>
</tr>
<tr>
<td>Prosulfuron 59% 64% 69% 69% 64% 64% 64% 64% 29% 30% 16% 30% 70% 100% 45%</td>
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</tr>
</tbody>
</table>

Mean recovery in 5 labs, all analytes:

- 0.01 mg/kg: 97% - 97%
- 0.1 mg/kg: 98% - 95%
Benefits of the QuEChERS method

• Fast (8 samples in 30 min instead of 1,5 days)
• Easy (no elaborate steps)
• Cheap (centrifuge is only equipment needed)
• Low amounts of solvents needed (10 mL acetonitrile)
• Minor use of glass ware
The only drawback ...

Work-up takes approx. 30 min.

Weighing the salts and SPE material is most tedious

- Pre-weighed sorbents and salts save work and time
- High-purity reagents from Sigma-Aldrich
- Convenient and reliable
# Ready-to-use products for QuEChERS for EN 15662:2008

<table>
<thead>
<tr>
<th>Prod. Nr.</th>
<th>Description</th>
<th>Content</th>
<th>Pack size</th>
<th>Tube volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>55227-U</td>
<td>Supel™ QuE Citrate Extraction Tube</td>
<td>magnesium sulfate, 4 g&lt;br&gt;sodium chloride, 1 g&lt;br&gt;sodium citrate dibasic x 1,5 H$_2$O, 0.5 g&lt;br&gt;sodium citrate tribasic x 2 H$_2$O, 1 g</td>
<td>pk of 50</td>
<td>12mL</td>
</tr>
<tr>
<td>55228-U</td>
<td>Supel™ QuE PSA Tube</td>
<td>Supelclean™ PSA, 150 mg&lt;br&gt;magnesium sulfate, 900 mg</td>
<td>pk of 50</td>
<td>12mL</td>
</tr>
<tr>
<td>55229-U</td>
<td>Supel™ QuE PSA/C18 Tube</td>
<td>Discovery® DSC-18, 150 mg&lt;br&gt;Supelclean™ PSA, 150 mg&lt;br&gt;magnesium sulfate, 900 mg</td>
<td>pk of 50</td>
<td>12mL</td>
</tr>
<tr>
<td>55230-U</td>
<td>Supel™ QuE PSA/ENVI-Carb Tube 1</td>
<td>Supelclean™ ENVI-Carb, 15 mg&lt;br&gt;Supelclean™ PSA, 150 mg&lt;br&gt;magnesium sulfate, 900 mg</td>
<td>pk of 50</td>
<td>12mL</td>
</tr>
<tr>
<td>55233-U</td>
<td>Supel™ QuE PSA/ENVI-Carb Tube 2</td>
<td>Supelclean™ ENVI-Carb, 45 mg&lt;br&gt;Supelclean™ PSA, 150 mg&lt;br&gt;magnesium sulfate, 900 mg</td>
<td>pk of 50</td>
<td>12mL</td>
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<td>55248-U</td>
<td>Supel™ QuE Empty Tube 50 mL</td>
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<td>pk of 50</td>
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<td>55284-U</td>
<td>Supel™ QuE Z-Sep/C18 Tube pk/100</td>
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<td>55296-U</td>
<td>Supel™ QuE Z-Sep+ Tube pk/50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
More information on QuEChERS

General:

 sigma-aldrich.com/quechers
 quechers.com

Custom QuEChERS tubes

 sigma-aldrich.com/custom-quechers

Reporter article „Intralab Validation QuEChERS/HPLC“

 Reporter QuEChERS-HPLC

Reporter article „Pesticides from Oranges by GC/MS“

 Reporter QuEChERS-GC
More information on QuEChERS

QuEChERS Brochure
Literature Code: NLJ

Literature Code QFW
www.sigma-aldrich.com/pesticides
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