

The Reporter

THE TECHNICAL NEWSLETTER FROM SUPELCO

Analysis of Glutathione on Ascentis™ RP-Amide with MS Detection

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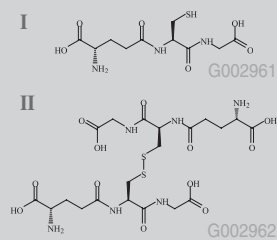
Introduction

Glutathione is the tripeptide γ -glutamylcysteinylglycine that serves as an important affecter of cellular redox status. Redox status is modulated by the relative ratio of the peptide in its reduced (GSH) and oxidized (GSSG) forms (Figure A). As a key cellular antioxidant,

researchers need to be able to assay the two forms in biological samples. Reversed-phase liquid chromatographic (RPLC) retention can be a challenge because the peptides are small and polar. A polar moiety in a bonded phase could provide advantages for retention and permit the use of a highly aqueous mobile.

Ascentis RP-Amide provides such a solution by being a polar embedded phase that is aqueous compatible and well-suited for mass spectral detection.

Figure A. Reduced (I) & Oxidized (II) Glutathione



A major experimental challenge in analyzing glutathione levels, both oxidized and reduced, from biological samples, is the artifactual oxidation of reduced glutathione that can take place during sample handling. Therefore, any method for such analysis must be able to address this issue.

Herein we demonstrate an application in which Ascentis RP-Amide is exploited for LC-MS analysis of small polar biological molecules.

Experimental Approach

First, an RPLC method is desired that can resolve at least three species: GSH, GSSG, and a derivative of GSH. The derivative of GSH will be generated as a means to control oxidation, as explained later.

Second, the derivatization of GSH (that would take place immediately upon extraction of a biological sample) must be shown to prevent auto-oxidation of GSH to GSSG.

Ascentis RP-Amide Resolves Glutathione Components

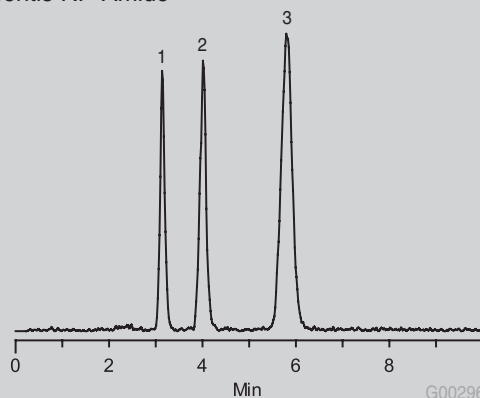
Figure B shows the resolution of all three components on Ascentis RP-Amide, made possible by

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Figure B. Resolution of All Glutathione Forms on Ascentis RP-Amide

column: Ascentis RP-Amide, 15 cm x 1.0 mm I.D., 5 μ m particles (custom)
mobile phase: 98:2, 25 mM formic acid titrated with ammonium hydroxide (pH 3.0):methanol
flow rate: 45 μ L/min
temp.: ambient
det.: ESI (+), XIC m/z = 308.4, 366.5, 613.0
injection: 1 μ L
sample: 30 mg/L GSH, 12 mg/L GSSG in 50 mM formic acid, 0.1 mM ethylenediaminetetraacetic acid

1. GSH; (M+H)⁺ = 308.4
2. Carboxymethylated GSH; (M+H)⁺ = 366.5
3. GSSH; (M+H)⁺ = 613.0



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the highly aqueous mobile phase. Sample was prepared by adding to a mixture of GSH and GSSG a submolar concentration (relative to GSH) of iodoacetic acid (IAA) in order to derivatize some of the GSH. The sample was incubated overnight and quenched by dilution into a low-pH buffer.

Alkylation Precludes Auto-oxidation

Auto-oxidation of GSH in biological samples leads to an artifactual formation of GSSG. Therefore it is necessary to include a derivatizing reagent in an extraction buffer in order to trap all GSH, precluding oxidation to GSSG.

In order to ascertain the efficacy of GSH derivatization by inclusion of IAA in a reaction mixture, alkylation of GSH was performed in the presence of an exogenous oxidant. This would mimic what would spontaneously occur in a biological extract. Therefore incubation of GSH with an oxidant [5-5'-Dithiobis-(2-nitrobenzoic acid)] was performed in the presence or absence of a molar excess (relative to GSH) of IAA. The oxidant was present at a 0.5% level relative to GSH (on a molar basis)

Figure C demonstrates that even in the presence of an oxidant, the alkylating agent IAA prevents formation of any GSSG. All GSH is trapped in the carboxymethylated form. In the absence of IAA, the included oxidant is effective in generating GSSG. These results demonstrate the viability of this strategy for processing of biological samples.

Conclusions

Ascentis RP-Amide provides an effective solution for analysis of GSH and GSSG by mass spectral detection. Alkylation of GSH by IAA is an effective strategy to prevent auto-oxidation, thus precluding artifactual generation of GSSG that would occur in processing biological samples. True levels of GSSG could then be obtained.

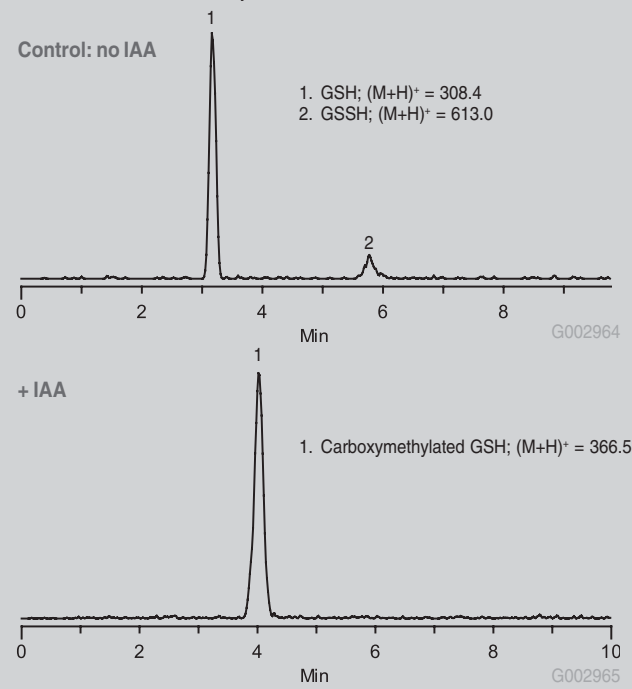
Comments

Iodoacetamide, another popular alkylating reagent for peptide sulfhydryls, also works as a substitute for IAA (data not shown). The elution of the carboxyamidomethylated GSH from Ascentis RP-Amide, under the conditions employed, immediately precedes that of GSH.

Sensitivity of the mass spectral detection could be improved by use of 3 μ m particles instead of the 5 μ m particles used in this study and/or a smaller ID column. With the column and detector employed, glutathione was detected at levels at least as low as 5ng (16 pmol GSH, 8 pmol GSSG) (data not shown).

Figure C. Efficacy of Trapping GSH in Alkylated Form

column: Ascentis RP-Amide, 15 cm x 1.0 mm I.D., 5 μ m particles
mobile phase: 98:2, 25 mM formic acid titrated with ammonium hydroxide (pH 3.0):methanol
flow rate: 45 μ L/min
temp.: ambient
det.: ESI (+), XIC m/z = 308.4, 366.5, 613.0
injection: 1 μ L
sample: 20 mg/L GSH in 50 mM formic acid,
0.1 mM ethylenediaminetetraacetic acid



Particle Size (μ m)	I.D. (mm)	Length (cm)	Cat. No.
Ascentis RP-Amide HPLC Columns			
3	2.1	5	565300-U
3	2.1	10	565301-U
3	2.1	15	565302-U
5	2.1	5	565303-U
5	2.1	10	565304-U
5	2.1	15	565305-U
5	2.1	25	565306-U

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Related Information

For the full details on the MS-compatibility of Ascentis RP-Amide, go to sigma-aldrich.com/thereporter, February 2005, 23.1.

For further information on Supelco's NEW Ascentis HPLC columns, request the Ascentis brochure, T404114 (HLV) or go to sigma-aldrich.com/ascentis

To request the NEW *Ascentis Applications CD* with over 90 applications, request T404125 (HNU).

New Supelpak™ -2SV Adsorbent Improves Environmental Sampling and Recovery of Difficult Semivolatile Compounds

Jim Walbridge
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Supelco announces the availability of its newest adsorbent, Supelpak-2SV, for environmental sampling and analysis. Environmental analysts performing analyses for semivolatile pollutants, dioxins, furans, polynuclear aromatic hydrocarbons (PAHs) and chlorinated pesticides will benefit from the use of Supelpak-2SV. Supelpak-2SV improves analyses by enhancing the recoveries of difficult compounds such as pentachlorophenol (PCP) and dinitrophenols allowing lower detection limits. Background levels are low enough to eliminate the need for additional cleaning steps, saving analysts time and money.

Background

Environmental analysts analyzing semivolatile pollutants according to various established methods (1) are required to collect samples using XAD®-2 resin. These methods specify laborious, time-consuming cleaning procedures to reduce background contaminants on XAD-2 to acceptable levels. Analysts often find the need to process “precleaned” XAD-2 even further to reduce background levels so that lower detection limits can be obtained by GC-MS analysis. Additionally, difficult compounds such as PCP and dinitrophenols must show high recoveries following extraction by XAD-2.

Improved Cleaning Process

For many years, Supelco has offered XAD-2 as well as Supelpak-2 and Supelpak-2B, precleaned versions of XAD-2, meeting cleanliness requirements of specific environmental

Table 1. Typical Background Levels Extracted from Supelpak-2SV and Competitors Products

Adsorbent	TCO Background* µg/g
Supelpak-2SV lot 1	0.52
Supelpak-2SV lot 2	0.67
Supelpak-2SV lot 3	0.51
Manufacturer B	4743
Manufacturer A	19.3

* Determined by GC/FID analysis. Sample prepared from 16-hour extraction of resin (40 grams) with dichloromethane

sampling methods (2). The Supelpak-2 series of resins has evolved to provide our customers with adsorbents that have lower background levels and increased recoveries for specific analytes. Our latest resin, Supelpak-2SV, is a dry and more highly purified version of XAD-2. Supelpak-2SV was developed specifically for the extraction and recovery of semi-volatile organic compounds from environmental samples. Produced using a proprietary cleaning process, Supelpak-2SV exhibits typical background levels of contaminants less than 1µg/g of resin measured as total chromatographable organics (TCO). Table 1 shows the low background levels extracted from Supelpak-2SV as analyzed on an Equity™-5 capillary GC column.

Improved Performance of Supelpak-2SV

Used straight from the bottle, Supelpak-2SV requires no costly in-house cleaning before use and is superior to other “precleaned” XAD-2 resins, even after additional cleaning.

(continued on page 4)

Table 2. Typical Recoveries of Phenols from Supelpak-2SV

Component	Recovery Lot #1910	Recovery Lot #1928	Recovery Lot #1932	Average Recovery 3 Lots	Competitor Data
Phenol	92	95	95	94	95
2-Chlorophenol	92	95	95	94	94
2-Methylphenol	93	95	95	94	92
2-Nitrophenol	93	95	96	95	95
2,4-Dimethylphenol	89	86	88	88	64
2,4-Dichlorophenol	89	90	93	91	100
2,4-Dinitrophenol	117	105	103	108	36
4-Nitrophenol	119	104	104	109	17
2,3,5,6-Tetrachlorophenol	113	104	106	108	112
2-Methyl 4,6-dinitrophenol	120	107	108	112	85
2,4,6-Tribromophenol	116	107	107	110	NA
Pentachlorophenol	123	109	108	113	85

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This results in savings in both lab time and hazardous solvent waste generation. Characterization by GC-MS has also shown Supelpak-2SV resin an excellent choice for semivolatiles priority pollutants, PCBs, PAHs and dioxins/furans. A study of extraction efficiencies using a wide range of semivolatiles compounds demonstrated recoveries in the 90% or greater range even for substituted phenols. Table 2 (page 3) shows typical recoveries of substituted phenols from Supelpak-2SV. Customers also appreciate other aspects of the product such as the availability of large single-lot batches of up to 10 kg. This significantly reduces a laboratory's labor for internal qualification for each lot of adsorbent.

Conclusion

Produced using proprietary cleaning procedures, Supelpak-2SV, a dry and more highly purified version of XAD-2, offers environmental analysts significantly lower background levels of organic contaminants eliminating the need for further cleaning prior to use. Notoriously difficult compounds such as PCP and dinitrophenols show extraction recoveries typically greater than 90% on Supelpak-2SV, improving the accuracy and reliability of analytical results. Your laboratory will save considerable time and money by switching to Supelpak-2SV for your environmental sample collection and extraction needs. Supelpak-2SV can be ordered in three different package sizes to meet your usage requirements.

References

1. US EPA SW-846, Method 0010, Method 8270C; California Air Resources Board (CARB) Methods 428 and 429, EPA Compendium Method TO-13A.
2. Supelpak-2 meets US EPA recommended criteria for purity in Level I Environmental Assessment Procedures Manual and as outlined in EPA SW-846, Method 10; Supelpak-2B meets EPA requirements for determining PCBs in water according to the Great Lakes National Program Office (GLNPO).

Supelpak-2SV

Description	Qty.	Cat. No.
Supelpak-2SV	100 g	13673-U
Supelpak-2SV	250 g	13682-U
Supelpak-2SV	1000 g	13674-U



Related Information

For more information on XAD-2 and the Supelpak family of adsorbents, request the Supelpak-2 resins product information sheet, T405056 (HXM).

Did you know...?

Supelpak-2SV can be obtained in single-lot batch sizes up to 10 kg. This will minimize the time that you spend on certifying different lots of adsorbent resin for your lab requirements. Specify your single lot needs at the time of order.

Supelco is one of the largest suppliers of small quantities of resins and media for research applications supplying research quantities of resins from Dow Chemical, Rohm & Haas and many other manufacturers. As these products demonstrate, we also routinely custom process resins to meet the exacting requirements of our customers through cleaning processes, repackaging or phase modification. For more information on our resin processing capabilities please contact Technical Service (800-359-3041/814-359-3041).



Related Products

Description	Qty.	Cat. No.	
Adsorbents			
Amberlite® XAD-2	100 g	20275	
Amberlite XAD-2	500 g	10357	
Supelpak-2	100 g	20279	
Supelpak-2	1 kg	21130-U	
Supelpak-2B	100 g	13670	
Equity-5 Capillary GC Columns			
30 m x 0.25 mm x 0.25 µm		28089-U	
30 m x 0.25 mm x 0.5 µm		28092-U	
Chemical Standards			
Semivolatiles Acid/Base Surrogate Spike Mix (Low) Varied in Methanol:Dichloromethane (90:10)	1 x 100 mL	861143	
2-Chlorophenol-d ₂ , 150 µg/mL	2-Fluorobiphenyl, 100 µg/mL	p-Terphenyl-d ₂ , 100 µg/mL	
1,2-Dichlorobenzene-d ₂ , 100 µg/mL	Nitrobenzene-d ₂ , 100 µg/mL	2,4,6-Tribromophenol, 150 µg/mL	
2-Fluorophenol, 150 µg/mL	Phenol-d ₂ , 150 µg/mL		
Semivolatiles Internal Standards Mix			
2000 µg/mL each in Dichloromethane	2 x 1 mL	48902	
Acenaphthene-d ₁₀	1,4-Dichlorobenzene-d ₂	Perylene-d ₂	
Chrysene-d ₂	Naphthalene-d ₂	Phenanthrene-d ₁₀	
CLP Semivolatiles Calibration Mix			
1000 µg/mL each in Dichloromethane: Benzene (3:1)	1 x 1 mL	506508	
Acenaphthene	4-Chloroaniline	4,6-Dinitro-2-methylphenol	Naphthalene
Acenaphthylene	4-Chloro-3-methyl phenol	2,4-Dinitrophenol	2-Nitroaniline
Anthracene	2-Chloronaphthalene	2,4-Dinitrotoluene	3-Nitroaniline
Azobenzene	2-Chlorophenol	2,6-Dinitrotoluene	4-Nitroaniline
Benzo[a]anthracene	4-Chlorophenyl phenyl ether	Di-n-octyl phthalate	Nitrobenzene
Benzo[b]fluoranthene	Chrysene	Fluoranthene	2-Nitrophenol
Benzo[k]fluoranthene	Dibenz[a,h]anthracene	Fluorene	4-Nitrophenol
Benzo[ghi]perylene	Dibenzofuran	Hexachlorobenzene	N-Nitrosodimethylamine
Benzo[a]pyrene	Di-n-butyl phthalate	Hexachlorobutadiene	N-Nitrosodi-n-propylamine
Bis(2-chloroethoxy)methane	1,2-Dichlorobenzene	Hexachlorocyclopentadiene	Pentachlorophenol
Bis(2-chloroethyl) ether	1,3-Dichlorobenzene	Hexachloroethane	Phenanthrene
Bis(2-chloroisopropyl) ether	1,4-Dichlorobenzene	Indeno[1,2,3-cd]pyrene	Phenol
Bis(2-ethylhexyl) phthalate	2,4-Dichlorophenol	Isophorone	Pyrene
4-Bromophenylphenyl ether	Diethyl phthalate	2-Methylnaphthalene	1,2,4-Trichlorobenzene
Butyl benzyl phthalate	2,4-Dimethylphenol	2-Methylphenol	2,4,5-Trichlorophenol
Carbazole	Dimethyl phthalate	4-Methylphenol	2,4,6-Trichlorophenol
TCL PAH Mix			
2000 µg/mL each in Dichloromethane: Benzene (50:50)	1 x 1 mL	48905-U	
Acenaphthene	Benzo[b]fluoranthene	Chrysene	Indeno[1,2,3-cd]pyrene
Acenaphthylene	Benzo[k]fluoranthene	Dibenz[a,h]anthracene	Naphthalene
Anthracene	Benzo[ghi]perylene	Fluoranthene	Phenanthrene
Benzo[a]anthracene	Benzo[a]pyrene	Fluorene	Pyrene

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NEW! Separate Source™ Aroclor Standards

Supelco now offers *Separate Source* (SS) Aroclor standards to meet US EPA requirements. These products have identical formulations but are prepared from independently sourced raw materials and quality controlled. Separate Source Aroclor standards provide the convenience of working with Supelco as a single vendor while enabling you to meet independent calibration and quality control requirements of the US EPA.

Each standard is prepared in isooctane and offered at 1000 µg/mL.

Standard	Qty.	Cat. No.
Aroclor 1016	1 mL	48097
NEW! SS Aroclor 1016	1 mL	458097
Aroclor 1221	1 mL	48098
NEW! SS Aroclor 1221	1 mL	458098
Aroclor 1232	1 mL	44805
NEW! SS Aroclor 1232	1 mL	454805
Aroclor 1242	1 mL	44806
NEW! SS Aroclor 1242	1 mL	454806
Aroclor 1248	1 mL	44807
NEW! SS Aroclor 1248	1 mL	454807
Aroclor 1254	1 mL	44808
NEW! SS Aroclor 1254	1 mL	454808
Aroclor 1260	1 mL	44809
NEW! SS Aroclor 1260	1 mL	454809
Aroclor 1262	1 mL	44810
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Aroclor 1268	1 mL	502146
NEW! SS Aroclor 1268	1 mL	5502146

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2-Methylisoborneol	1 mL	47523-U
NEW! 5 x 2 mL		4M7523-U
(+/-)Geosmin and 2-Methylisoborneol	1 mL	47525-U
NEW! 5 x 2 mL		4M7525-U

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Description	Qty.	Cat. No.
0.5 µm	Pk/10	55214-U
2.0 µm	Pk/10	55215-U

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Description	Cat. No.
1 L bottle	55060-U
2 L bottle	55061

SupelPRO 2-Position Valves



Supelco offers SupelPRO™ an electronically-controlled, motorized valve instrument for repetitive fluid switching operations. The SupelPRO 2-position valve, useful for a wide variety of applications including sample clean-up and backflushing, is self-contained and comes with either 6 or 10 port in PEEK or stainless steel. The 2-position models are 1-line control, level logic for automated control through the communication interface. Power requirements: 100-240 VAC, 50-60Hz (auto switching). All units shipped with standard US power cord. Other power cords are available on a custom basis. All SupelPRO units are CE approved.

Description	Material	Cat. No.
6-Port	stainless steel	53148-U
6-Port	PEEK	53149-U
10-Port	stainless steel	53150-U
10-Port	PEEK	53151-U

Rheodyne® Model 7125 Injector

The Rheodyne Model 7125 syringe loading injector allows injection of the entire contents of the syringe into the sample loop – you will not have to flush the valve between injections, unless you are conducting trace analyses. It also injects samples from a partially filled loop (you save time by not having to change the sample loop).



The Model 7125 injector can be used at pressures to 7000 psi (490 kg/cm²) and is supplied with a VESPEL® rotor seal for operation at pH 0-10. A 20 mL sample loop is included; order additional loops separately.

Description	Cat. No.
Rheodyne Model 7125 Injector	58826

Extraction of Pesticides from Agricultural Matrices Using Dual-Layer SPE Technology

An Trinh

atrinh@sial.com

The multi-residue surveillance of pesticides in agricultural/food products is an ongoing project for regulatory agencies and industrial laboratories worldwide. Hundreds of thousands of samples are analyzed annually to meet a variety of purposes including regulatory enforcement and surveillance monitoring.

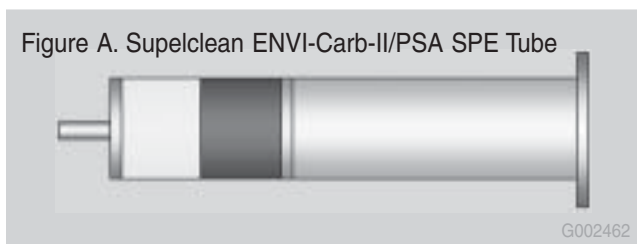
A number of procedures have been published for the extraction and analyses of multi-residue pesticides from a variety of food matrices. Most of which involve an initial liquid-liquid extraction step, and/or solid-liquid extraction step using a water miscible solvent followed by GC analyses. Prior to GC analyses, further sample cleanup is necessary to decrease background levels for trace pesticide detection, reduce matrix-induced signal enhancement, and relieve stress on the GC system.

In this report we discuss the utility of dual-layer ENVI-Carb™-II/PSA technology for the removal of matrix interferences when conducting GC-MS analysis of multi-residue pesticides in agricultural products.

SPE Sorbent Description

The Supelclean™ ENVI-Carb-II/PSA SPE product line consists of multi-layer SPE cartridges (Figure A) that were developed for superior sample cleanup when conducting multi-residue pesticide analysis from food (fruits, vegetables, meat, shellfish, grains, and dairy products). Each layer plays a specific role for removing key interferences when conducting pesticide analysis using GC.

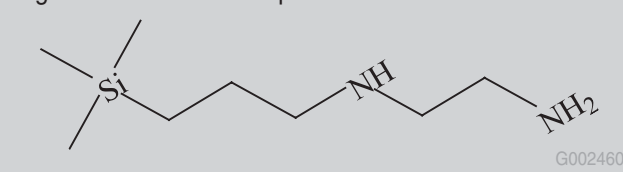
Figure A. Supelclean ENVI-Carb-II/PSA SPE Tube



Supelclean ENVI-Carb-II SPE is a graphitized non-porous carbon (100/140 mesh, surface area 100 m²/g) that has a strong affinity towards planar molecules, and has been quality controlled specifically for the isolation/removal of pigments (e.g., chlorophyll and carotinoids) and sterols commonly present in fruits, vegetables and other natural products.

Supelclean PSA SPE is a polymerically bonded, ethylenediamine-N-propyl phase (Figure B) that contains both primary and secondary amines. The phase has a strong affinity and high capacity for removing up to 99% of fatty acids (oleic, palmitic and linoleic acid), organic acids, and some polar pigments and sugars when conducting multi-residue pesticide analysis in foods. By removing these interferences, it has been shown to greatly reduce matrix-induced response enhancement encountered during the GC-analyses of food products.

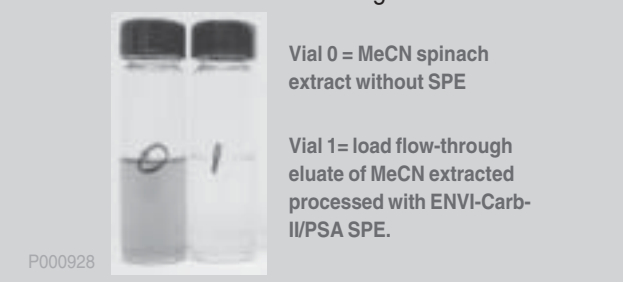
Figure B. Structure of Supelclean PSA SPE



Decolorization of Vegetable Extracts using Supelclean ENVI-Carb-II

In this study, 25 g of fresh spinach was homogenized with 50 mL MeCN. The MeCN spinach extracts were loaded onto an ENVI-Carb-II/PSA SPE tube (500 mg/500 mg/6 mL) pre-conditioned with 5 mL MeCN:toluene (3:1). The load flow-through eluate was collected and depicted in Figure C.

Figure C. Spinach Extracts With and Without Further ENVI-Carb-II/PSA SPE Processing



Cleanup of Milk Prior to GC-MS Analyses

20 mL of fresh milk (2% fat) was extracted with 50 mL acetonitrile. 10 g sodium chloride was added, the extract was shaken for 1 min., and phase partitioned for 15 min. The upper acetonitrile layer was aliquoted, and 4 g of anhydrous magnesium sulfate was added. After vigorous shaking, the extract was centrifuged for, and the supernatant was evaporated to 0.5 mL under N₂, 40 °C, and reconstituted with 1 mL with ac-

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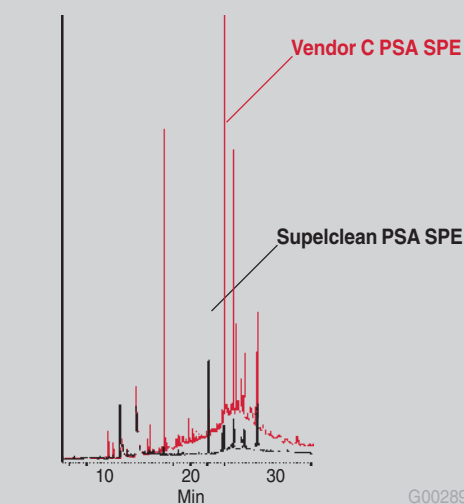
SPE

SUPELCO

etonitrile. The acetonitrile extract was loaded onto both a Supelclean PSA SPE tube, 500 mg/6 mL; and competitor PSA SPE tube (Vendor C) pre-conditioned with 5 mL acetonitrile followed by 14 mL acetonitrile elution. The eluate was further concentrated under N_2 , and reconstituted with 1 mL acetone:hexane (1:1) for subsequent GC-MS screening (Figure D). As observed in Figure D, background interference noise on Supelclean PSA SPE was substantially reduced when compared to Vendor C PSA SPE.

Figure D. GC-MS Analysis of Milk Extract Subjected to PSA SPE Sample Cleanup

column: Equity-5, 30 m x 0.25 mm I.D., 0.25 μ m (28089-U)
 oven: 50 °C (5 min.), 25 °C/min. to 125 °C, 10 °C/min. to 300 °C (8 min.)
 inj.: 200 °C; aux: 325 °C
 det.: MSD, scan range 45-450 amu
 carrier: helium, 0.9 mL/min., constant flow mode
 injection: 1 μ L, splitless (splitter open at 1 min.)
 liner: 4 mm I.D., single taper
 tune: generated using ATUNE tuning macro



G002890, G002891

This report illustrates some preliminary data regarding the role of each of the sorbents for multi-layer ENVI-Carb-II/PSA SPE products for pesticide analysis of food samples. When processing actual samples using the protocol described in Table 1, multi-layer ENVI-Carb-II/PSA SPE tubes act as a chemical filter for the isolation/removal of key interferences commonly associated with pesticide analysis of food products.

Table 1. Supelco Recommended Extraction Protocol for Pesticides in Food

Pre-SPE Extraction:

1. For solid samples with less than 2% fat content (e.g., chopped vegetables/fruits), combine every 10g food product with 20mL MeCN; vortex/shake 1 min. For liquid samples (e.g. milk) combine every 10mL food product with 20mL MeCN; vortex/shake 1 min.
2. Add 10g NaCl for every 20mL MeCN used for extraction; Add I.S. as necessary
3. Homogenize the samples
4. Centrifuge or filter to remove particulate matter
5. Transfer MeCN layer to a separate vessel
6. Dry MeCN layer over anhydrous Na_2SO_4 or $MgSO_4$
7. Evaporate MeCN extract and reconstitute as necessary to achieve a final MeCN extract volume of 1 mL

SPE:

8. Condition multi-layer Supelclean ENVI-Carb-II/PSA SPE Cartridge with 5 mL MeCN:toluene (3:1)
9. Load MeCN extract from step 7
10. Elute weakly retained pesticides with 20 mL MeCN:toluene (3:1)
11. Evaporate MeCN:toluene eluate (3:1); and reconstitute with acetone:hexane (1:1)



Related Information

For a full technical report describing the utility of Multi-Layer ENVI-Carb-II/PSA SPE, please request T405060 (HYA). The technical report provides pesticide recovery data, additional applications/protocols, part numbers, references, and suggested readings.

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