

Preservatives

Preservation techniques are used in foods and beverages to maintain the quality of the product. Food preservation can be done by both physical and chemical means. Physical techniques might involve drying, heating, freezing, pasteurization, or irradiation; chemical techniques include adding sugar, salt, or preservatives. Several common chemicals, such as acetic acid and citric acid, can be used to prevent the growth of food-spoiling microorganisms. Calcium propionate can be used to prevent mold growth. In addition, benzoate and sorbate salts can be used as mold inhibitors in a range of food and beverage products.

Benzoate and sorbate salts can be analyzed in their protonated form (i.e., as benzoic acid and sorbic acid) by reversed phase HPLC using an **Ultra Phenyl** column and acidified water:methanol (80:20, v/v) as the mobile phase. By monitoring the UV absorbance at 245nm, sensitive detection of benzoic and sorbic acids can be achieved. For optimum sensitivity, monitor benzoic acid at 230nm and sorbic acid at 254nm.

Analyze phenolic antioxidants by reversed phase HPLC using a **Pinnacle II™ C18** column and an acidic mobile phase.

for more info

Request Flyer **High Performance Silica Products** (cat.# 59901).

Sorbic Acid and Benzoic Acid Ultra Phenyl

HPLC

Peak List:

1. sorbic acid
2. benzoic acid

Sample:

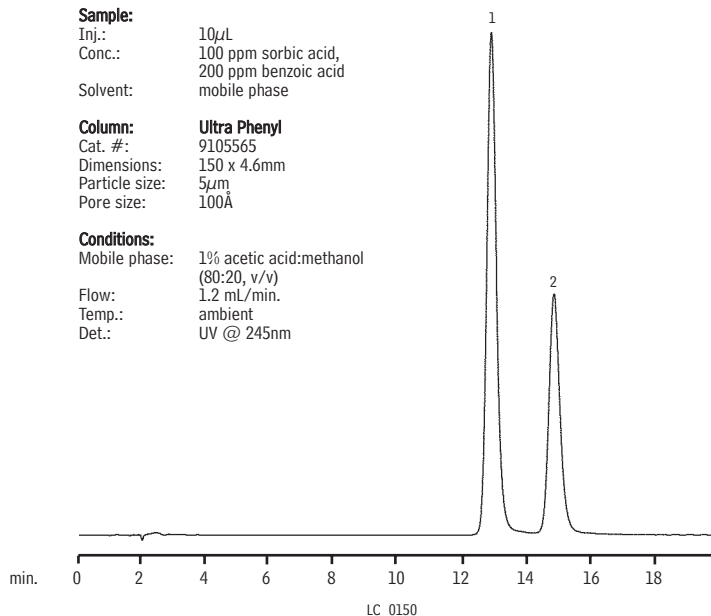
Inj.: 10 μ L
 Conc.: 100 ppm sorbic acid,
 200 ppm benzoic acid
 Solvent: mobile phase

Column: Ultra Phenyl

Cat. #: 9105565
 Dimensions: 150 x 4.6mm
 Particle size: 5 μ m
 Pore size: 100Å

Conditions:

Mobile phase: 1% acetic acid:methanol
 (80:20, v/v)
 Flow: 1.2 mL/min.
 Temp.: ambient
 Det.: UV @ 245nm



Phenolic Antioxidants Pinnacle II™ C18

HPLC

Peak List:

- | Peak List: | conc.: (ppm) |
|-------------------|--------------|
| 1. propyl gallate | 168 |
| 2. TBHQ | 182 |
| 3. 2-BHA + 3-BHA | 197 |
| 4. BHT | 193 |

Column: Pinnacle II™ C18

Cat. #: 9214565
 Dimensions: 150 x 4.6mm
 Particle size: 5 μ m
 Pore size: 110Å

Sample:

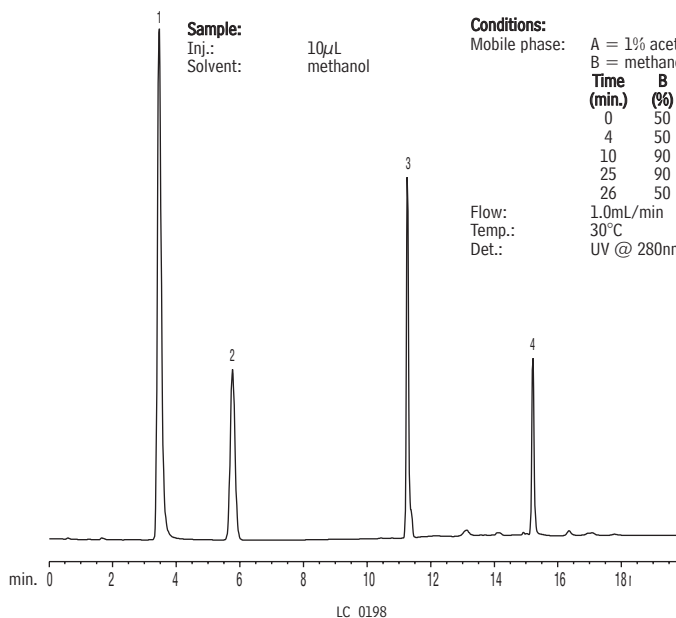
Inj.: 10 μ L
 Solvent: methanol

Conditions:

Mobile phase: A = 1% acetic acid
 B = methanol

Time (min.)	B (%)
0	50
4	50
10	90
25	90
26	50

Flow: 1.0mL/min
 Temp.: 30°C
 Det.: UV @ 280nm

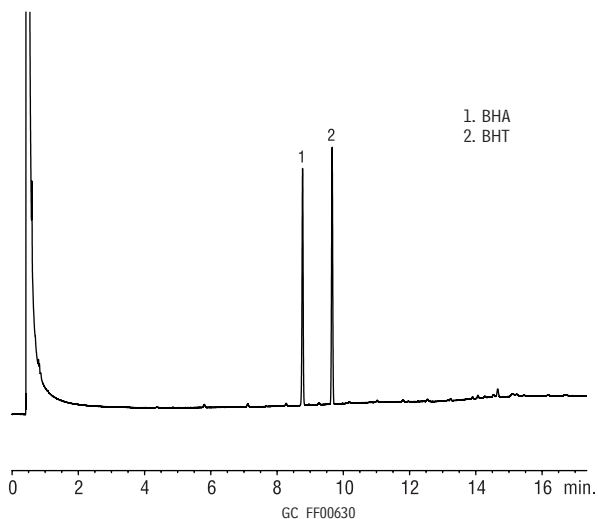


Foods containing fats and oils are prone to lipid oxidation, which can promote off-flavors and limit shelf-life. To inhibit lipid oxidation, antioxidants can be added to the product. Phenolic antioxidants, including butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG), and tert-butyl hydroquinone (TBHQ), are used in a variety of products. Phenolic antioxidants are regulated by the FDA and can be added to the product at levels up to 200ppm based on the fat content. Another approach is to use “natural” antioxidants, such as tocopherols and tocotrienols. These compounds inhibit lipid oxidation and promote general health in the consumer.

Phenolic antioxidants can be analyzed by GC using intermediate polarity **Rtx®-50** or **Rtx®-20** capillary columns. Coelutions that can occur with less polar columns can be avoided. Using direct injection and a flame ionization detector, BHA and BHT can be separated in less than 10 minutes. Using an **Rtx®-20** column, tocopherols from the unsaponified fraction of animal and vegetable fats and oils can be analyzed in their free form without derivatization. Baseline resolution is possible, with analyses times of less than 10 minutes.

BHA and BHT Rtx®-50

GC



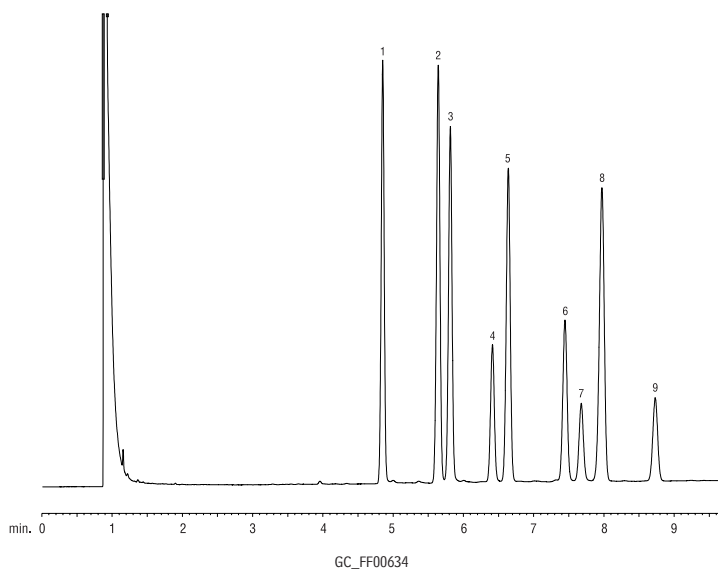
Rtx®-50, 30m, 0.53mm ID, 0.50 μ m (cat.# 10540)
 Sample: 50ppm each in methanol
 Inj.: 1.0 μ L direct injection, gooseneck splitless inlet liner, 4mm (cat.# 20798)
 Inj. temp.: 280°C
 Carrier gas: helium, constant pressure
 Linear velocity: 60cm/sec. @ 50°C
 Oven temp.: 50°C to 240°C @15°C/min. (hold 3 min.)
 Det.: FID @280°C

Tocopherols and Tocotrienols Rtx®-20

GC

1. δ -tocopherol
2. β -tocopherol
3. γ -tocopherol
4. dl- δ -tocotrienol
5. α -tocopherol
6. dl- β -tocotrienol
7. dl- γ -tocotrienol
8. hexadecyl hexadecanoate
9. dl- α -tocotrienol

Rtx®-20, 30m, 0.53mm ID, 0.5 μ m (cat.# 10340)
 Sample: 1mg/mL each component in isoocetane
 Inj.: 1.0 μ L split (split ratio 20:1),
 4mm inlet liner (cat.# 20814)
 Inj. temp.: 320°C
 Carrier gas: hydrogen, constant flow
 Flow rate: 5.2mL/min.
 Oven temp.: 270°C to 290°C @ 2°C/min.
 290°C to 320°C @ 10°C/min. (1 min. hold)
 Det.: FID @ 320°C



for more info

Request Application Note **HPLC Analysis of Preservatives Using Ultra Aqueous and Pinnacle II™ Columns** (cat. # 59398).

Flavors & Fragrances

Flavor consists of the taste, the aroma, and the trigeminal response to a compound. The aroma of a compound can be exceedingly complex, with several hundred volatiles playing a role. Because the nose can be extremely sensitive to some odorants, trace-level analyses may be necessary. Off-flavors can result from chemical changes in foods, microbial growth, or contamination. Chemical changes include lipid oxidation, nonenzymatic browning, and enzymatic action in the food.

Vanilla Extracts and Flavorings

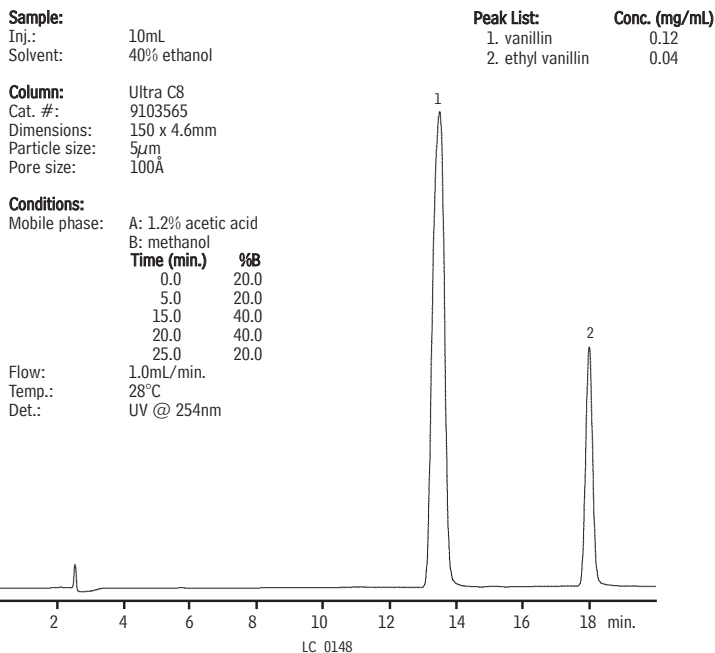
One example of flavor analysis is the determination of the compounds present in vanilla extracts and flavorings. Vanilla extracts and flavorings are used in a wide range of food products, including dairy products, beverages, baked goods, and confections. In AOAC Method 990.25, flavor compounds in vanilla extract and artificial vanilla flavor are analyzed using HPLC. The analytes are separated on a C8 column and quantified by comparing their UV absorbance at 254nm to an external standard. An efficient separation can be performed using an **Ultra C8** reversed phase HPLC column and a gradient elution program, with acidified water:methanol as the mobile phase. By using a gradient program and flow rate of 1mL/min., the analysis time can be reduced to 25 minutes.

for more info

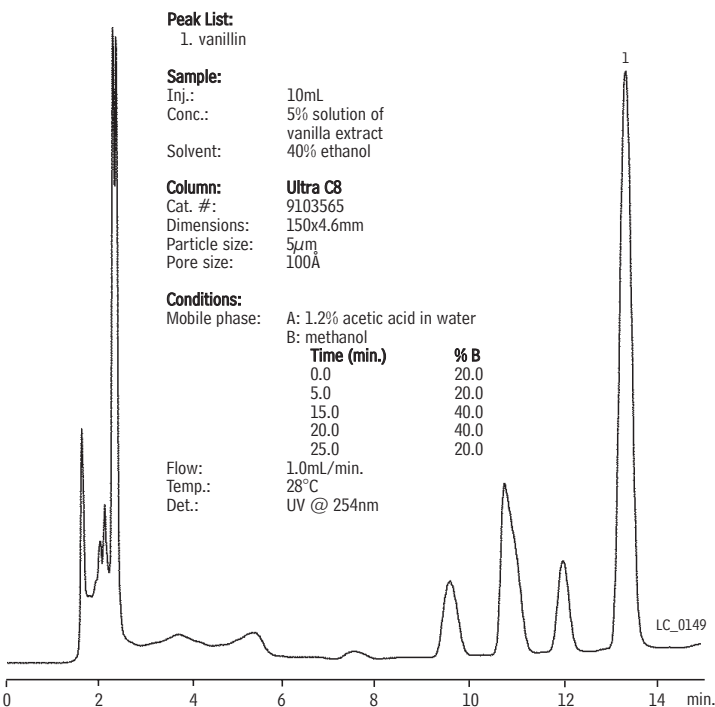
Request Application Note **Analysis of Vanillin and Ethyl Vanillin in Vanilla Flavors Using Ultra C8 Column** (cat. # 59186).

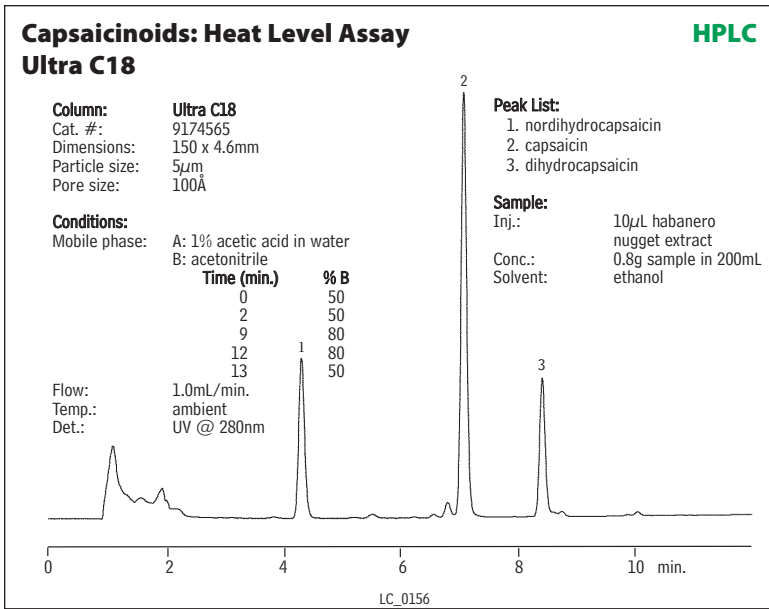
Vanillin and Ethyl Vanillin
Ultra C8

HPLC

Vanilla Extract
Ultra C8

HPLC



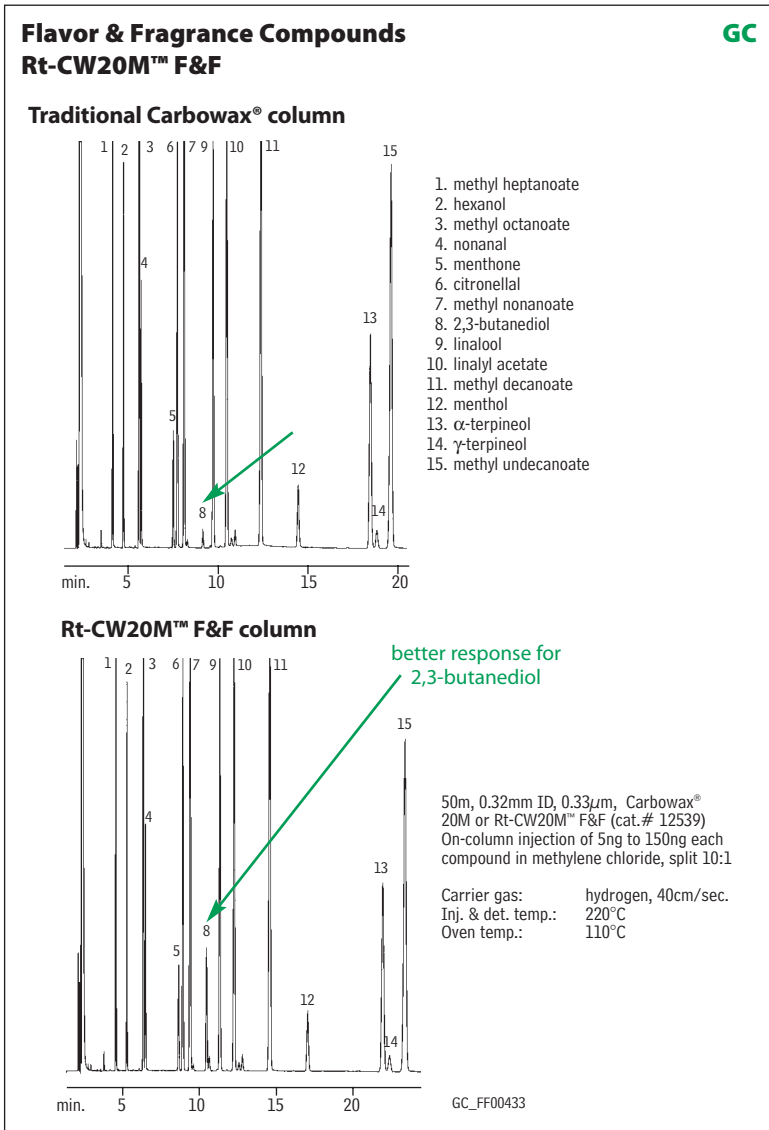


Heat Levels of Spicy Foods

The hotness of chili peppers, salsas, and other spicy foods can be monitored using HPLC. By measuring the levels of three different capsaicinoid species in the sample, the heat level in Scoville Heat Units (SHUs) can be calculated. AOAC Method 995.03 is a reversed phase HPLC method that calls for a C18 column and acidified water:acetonitrile as the mobile phase to separate nordihydrocapsaicin, capsaicin, and dihydrocapsaicin. This separation can be performed using an **Ultra C18** column. Using a gradient elution program, an efficient separation can be performed in less than 10 minutes. The high percentage of organic in the mobile phase at the end of the analysis helps elute any strongly retained species.

Flavor & Fragrance Volatiles

Flavor and fragrance analysts have compiled retention index libraries for thousands of compounds. Unfortunately, even slight changes in column selectivity can result in misidentification of compounds. With this in mind, Restek developed the **Rtx®-1 F&F** column. This polymer matches the selectivity required by the industry, while offering higher thermal stability. Additionally, **Rt-CW20M™ F&F** columns feature a non-bonded phase designed specifically for flavor and fragrance compounds. **Rt-CW20M™ F&F** columns exhibit better inertness than other non-bonded Carbowax® columns.



for more info

Request Application Note **Analyzing the Heat Level of Spicy Foods Using an Ultra C18 HPLC column** (cat. # 59199).

Flavors & Fragrances

Alcoholic Beverages

The chromatographic profile of alcoholic beverages consists of a wide range of compounds, including acids, alcohols, and aldehydes. GC can be used to analyze these compounds without the need for preliminary extractions.

An **Rtx®-1301** or **MXT®-1301** capillary column provides efficient separation of the volatile organic compounds in alcoholic beverages. Packed columns, such as **CarboBlack™ B** with a **5% Carbowax® 20M** phase, are an excellent alternative for these compounds. **CarboBlack™** columns are made using SilcoSmooth™ stainless steel tubing with a deactivated silica inner layer. This improves inertness, durability, and flexibility over traditional glass packed columns.

for more info

Request Technical Guide **Analyzing Alcoholic Beverages by Gas Chromatography** (cat.# 59462).

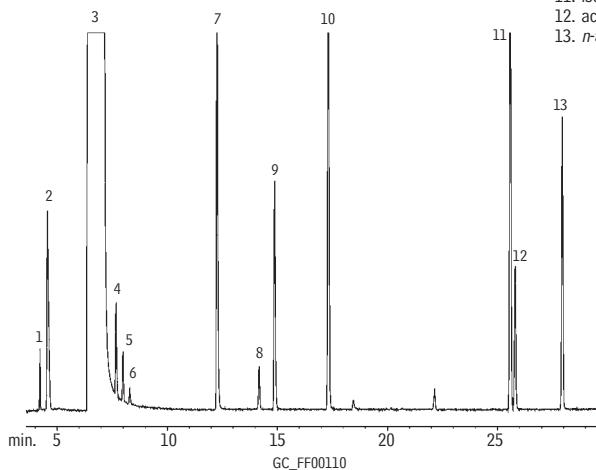
Rum Rtx®-1301

GC

60m, 0.25mm ID, 1.4µm Rtx®-1301 (cat.# 16016)
1.0µL split injection using a Cycloplitter® liner (cat.# 20706).
Conc.: neat

Oven temp.: 35°C (hold 5 min.) to 100°C @ 1°C/min.
Inj./det. temp.: 150°C / 200°C
Carrier gas: hydrogen @ 40cm/sec.
Split ratio: 100:1

1. acetaldehyde
2. methanol
3. ethanol
4. acetone
5. ethyl formate
6. isopropanol
7. *n*-propanol
8. ethyl acetate
9. *sec*-butanol
10. isobutanol
11. isoamyl alcohol
12. active amyl alcohol
13. *n*-amyl alcohol



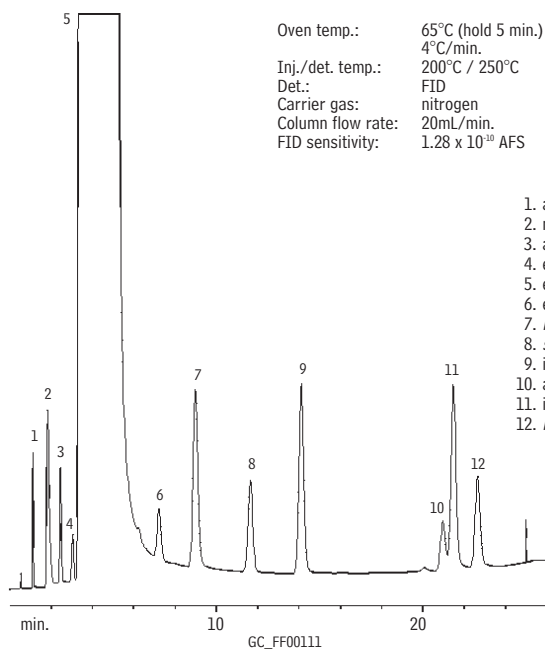
Rum CarboBlack™ B

PACKED GC

5% Carbowax® 20M 80/120 CarboBlack™ B (cat.# 80105)
2m, 1/8" OD x 2mm ID SilcoSmooth™ tubing
0.5µL on-column injection
Conc.: neat

Oven temp.: 65°C (hold 5 min.) to 150°C @
4°C/min.
Inj./det. temp.: 200°C / 250°C
Det.: FID
Carrier gas: nitrogen
Column flow rate: 20mL/min.
FID sensitivity: 1.28 x 10⁻¹⁰ AFS

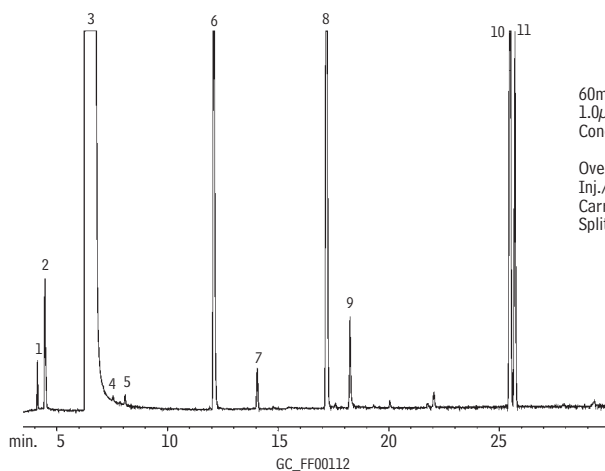
1. acetaldehyde
2. methanol
3. acetone
4. ethyl formate
5. ethanol
6. ethyl acetate
7. *n*-propanol
8. *sec*-butanol
9. isobutanol
10. active amyl alcohol
11. isoamyl alcohol
12. *n*-amyl alcohol



**Scotch
Rtx®-1301**

GC

- 1. acetaldehyde
- 2. methanol
- 3. ethanol
- 4. acetone
- 5. isopropanol
- 6. *n*-propanol
- 7. ethyl acetate
- 8. isobutanol
- 9. acetic acid
- 10. isoamyl alcohol
- 11. active amyl alcohol



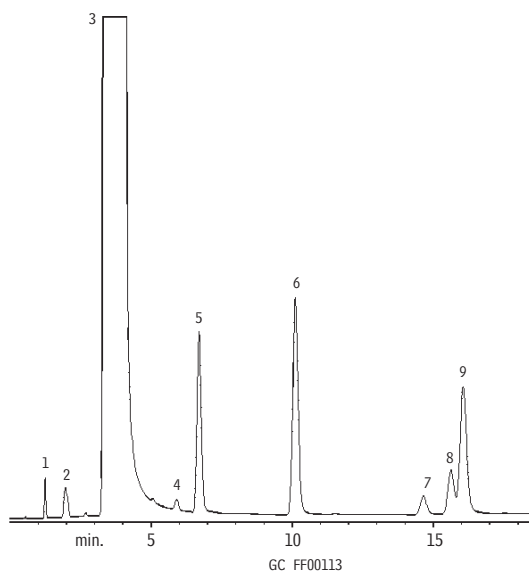
60m, 0.25mm ID, 1.4µm Rtx®-1301 (cat.# 16016)
1.0µL split injection using a Cyclosplitter® inlet liner (cat.# 20706).
Conc.: neat

Oven temp.: 35°C (hold 5 min.) to 100°C @ 1°C/min.
Inj./det. temp.: 150°C / 200°C
Carrier gas: hydrogen @ 40cm/sec.
Split ratio: 100:1

**Scotch
CarboBlack™ B**

PACKED GC

- 1. acetaldehyde
- 2. methanol
- 3. ethanol
- 4. ethyl acetate
- 5. *n*-propanol
- 6. isobutanol
- 7. acetic acid
- 8. active amyl alcohol
- 9. isoamyl alcohol



5% Carbowax® 20M 80/120 CarboBlack™ B (cat.# 80105)
2m, 1/8" OD x 2mm ID Silcosmooth™ tubing
0.5µL on-column injection
Conc.: neat

Oven temp.: 70°C to 150°C @ 4°C/min.
Inj./det. temp.: 200°C / 250°C
Det.: FID
Carrier gas: nitrogen
Column flow rate: 20mL/min.
FID sensitivity: 1.28 x 10⁻¹⁰ AFS

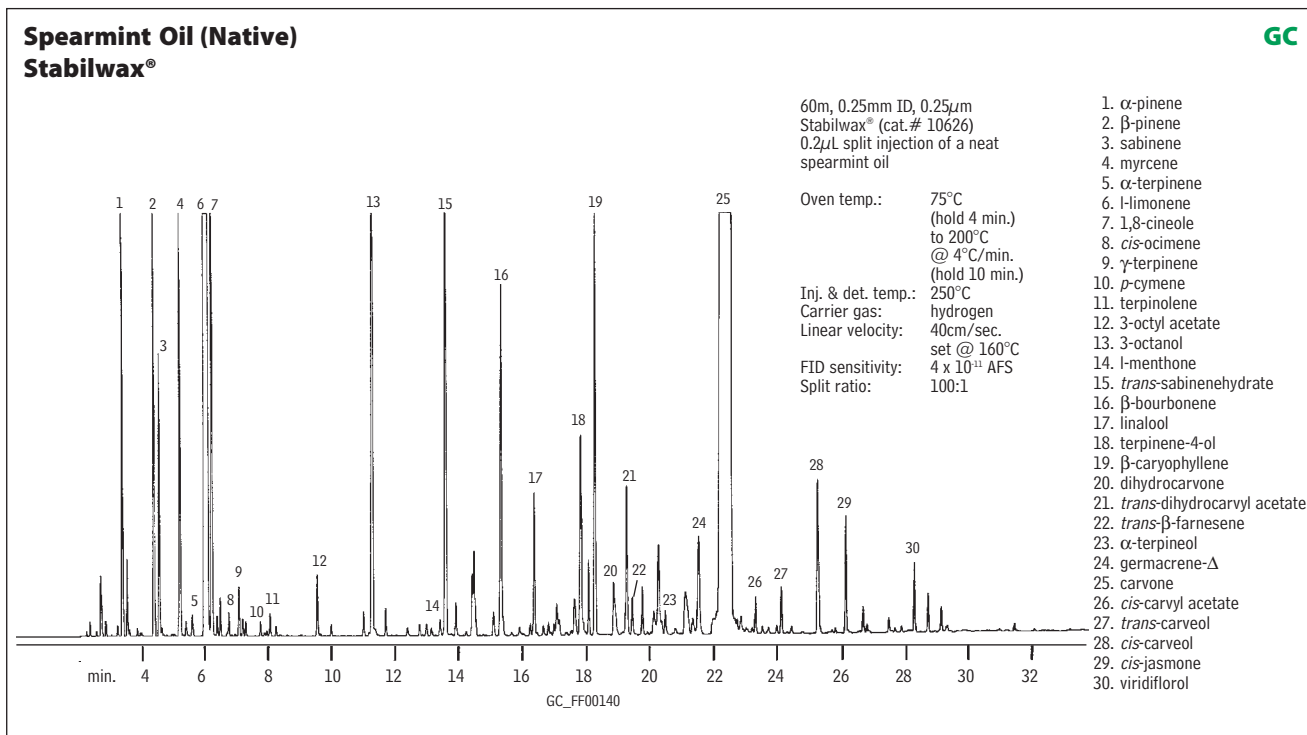
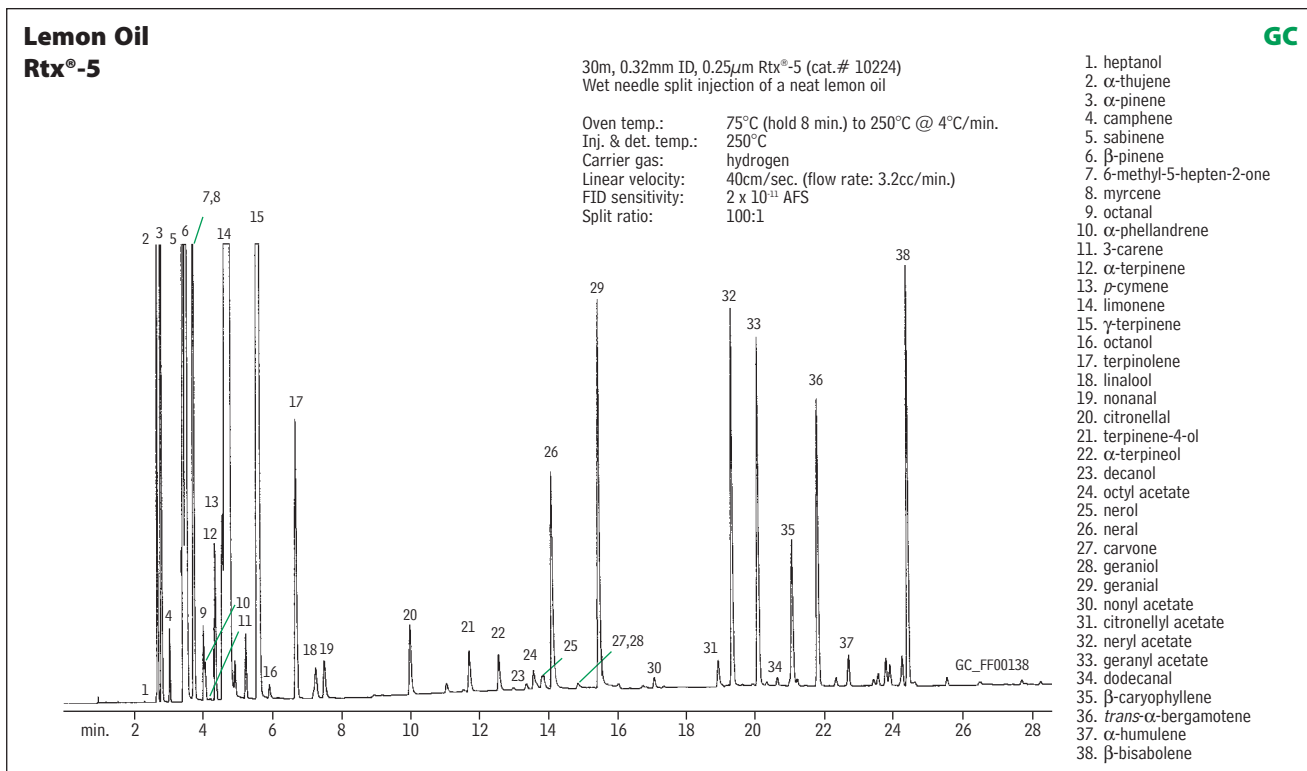
for **more** info

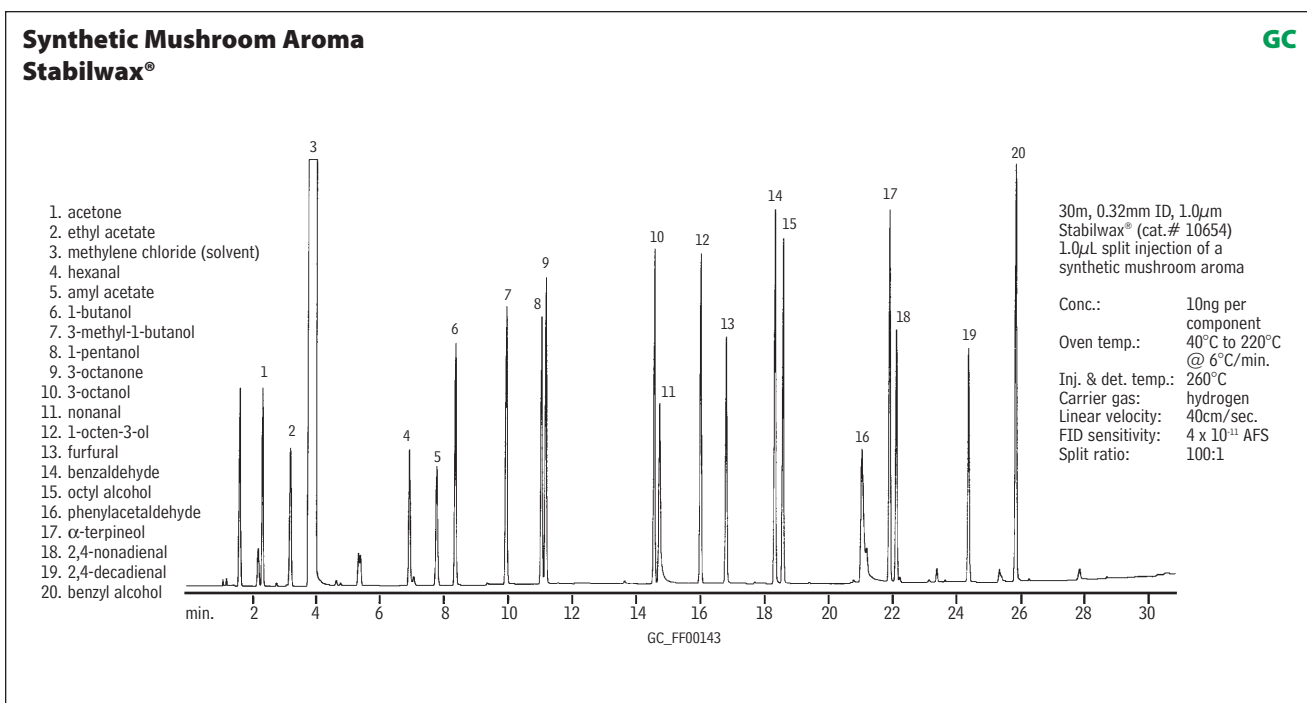
Request Technical Guide **Analyzing Alcoholic Beverages by Gas Chromatography** (cat.# 59462).

Essential Oils

Essential oil samples are very complex; hundreds of components can be present and some are present at ppm levels. **Rtx®-1**, **Rtx®-5** and **Stabilwax®** capillary GC columns are very effective for these analyses. A comprehensive list of retention times for flavor & fragrance compounds on **Rtx®-1** and **Stabilwax®** columns is on pages 28–29.

To determine the enantiomeric ratios of volatile components in essential oils, see Chiral Separations (pages 23–26).

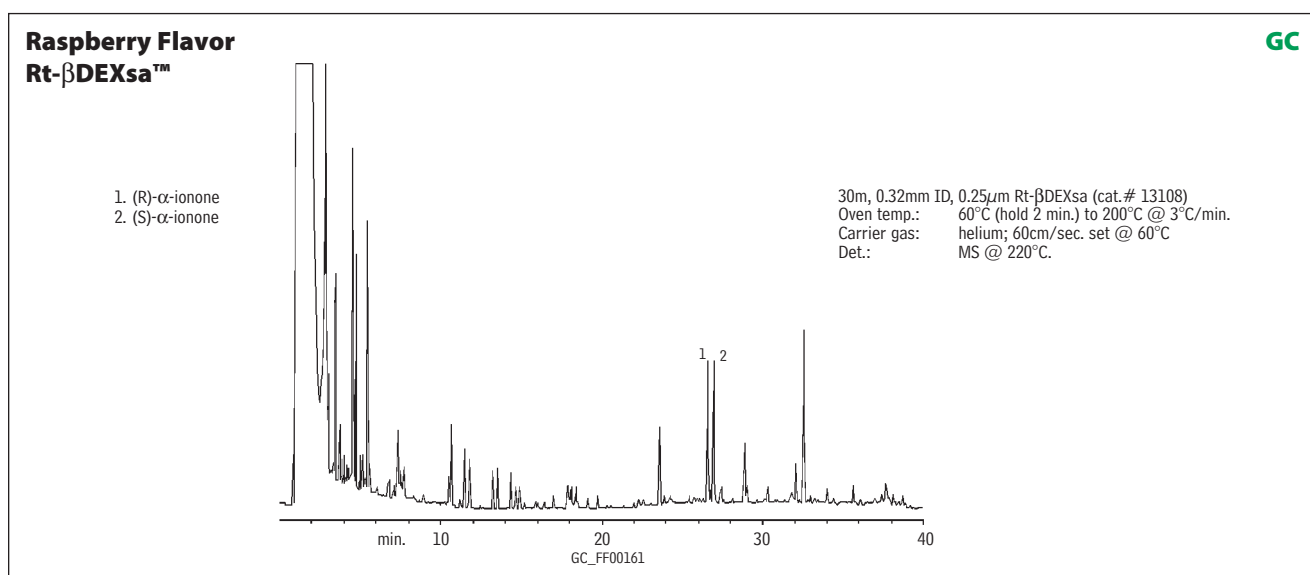




Chiral Separations

Chiral chromatography is the separation of enantiomeric compounds, which are mirror images of each other that are not superimposable. Common liquid stationary phases used in GC typically are not able to resolve enantiomeric compounds. However, the addition of derivatized cyclodextrin molecules to common stationary phases makes such separations possible. Restek's five chiral capillary columns incorporate various combinations of alkylated β -cyclodextrins into a cyanopropyl-dimethyl siloxane liquid stationary phase. The unique combinations of cyclodextrins allow analysis of a wide range of enantiomeric compounds.

Chiral capillary chromatography is a relatively new technique for determining the enantiomeric ratios of volatile components in essential oils. Enantiomeric ratios can be used for determining the authenticity of an essential oil or for characterizing regional differences among oils. The separation of enantiomeric compounds in flavor and fragrance samples can be optimized through column selection. Each of the five Restek chiral columns offers a different selectivity. The **Rt- β DEXsp™** column is optimized for menthol analysis, while the **Rt- β DEXsa™** column provides the best separation for 1-octen-3-ol, carvone, camphor, 1-phenylethanol, β -citronellol, and rose oxides. **Rt- β DEXsm™** and **Rt- β DEXse™** columns, used in combination, provide the best resolution for *cis*- and *trans*-linalool oxides, linalool, and linalyl acetate. The **Rt- β DEXcst™** column is ideal for semivolatile chiral compounds, including the irone isomers and γ - and δ -lactones.



Chiral Separations

Flavor chemists can use chiral chromatography to monitor the ratios of various enantiomeric compounds. γ -lactones, for example, can be monitored to determine if a peach flavor has been adulterated. Ethyl-2-methylbutyrate and 2-methylbutyrate are important contributors to apple flavor, and both are naturally present in predominantly the (S) form in apple juices. The enantiomers of these two compounds can be resolved on an **Rt- β DEXsm™** column.

for **more info**

Request **Chiral Column Technical Guide** (cat.# 59889).

tech tip

To optimize chiral separations, use:

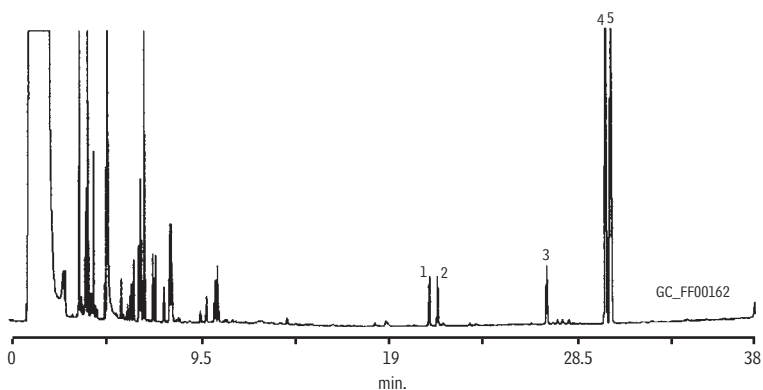
- 1) Faster linear velocities (80cm/sec.) with hydrogen carrier gas.
- 2) Slower temperature ramp rates (1–2°C/min.).
- 3) Appropriate minimum operating temperature (40 or 60°C).
- 4) On-column concentrations of 50ng or less.

Peach/Vanilla Flavor Rt- β DEXsa™

GC

1. (R)- γ -octalactone
2. (S)- γ -octalactone
3. (R)- γ -decalactone
4. (R)- γ -undecalactone
5. (S)- γ -undecalactone

30m, 0.32mm ID, 0.25 μ m Rt- β DEXsa™ (cat.# 13108)
 Oven temp.: 60°C (hold 2 min.) to 100°C @ 15°C/min.
 to 220°C @ 3°C/min.
 Carrier gas: helium, 60cm/sec. set @ 60°C
 Det.: MS @ 220°C

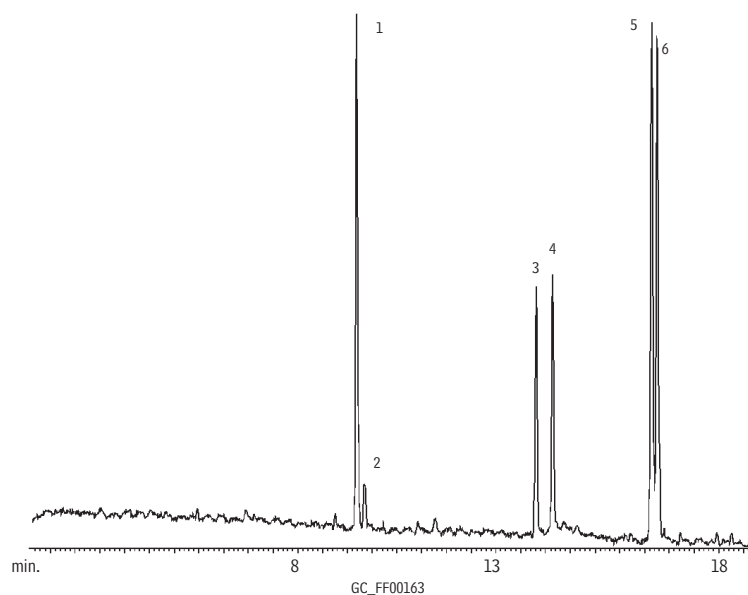


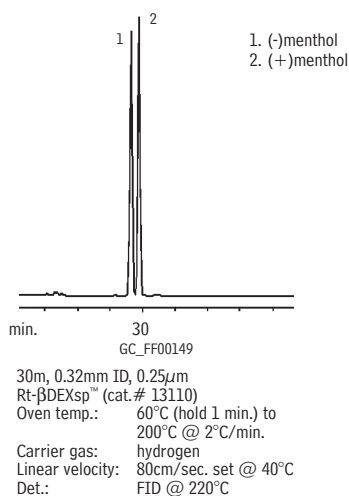
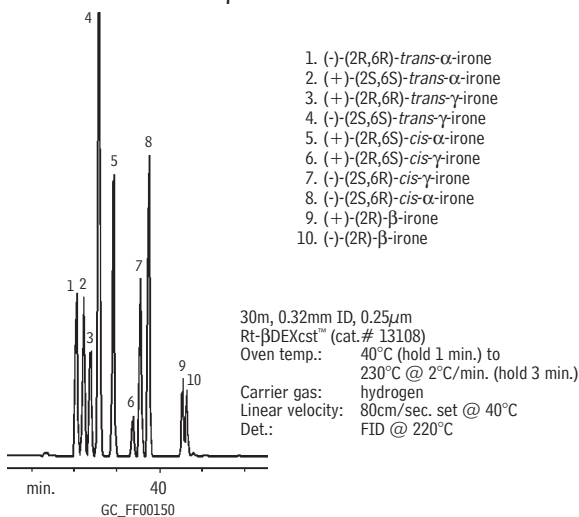
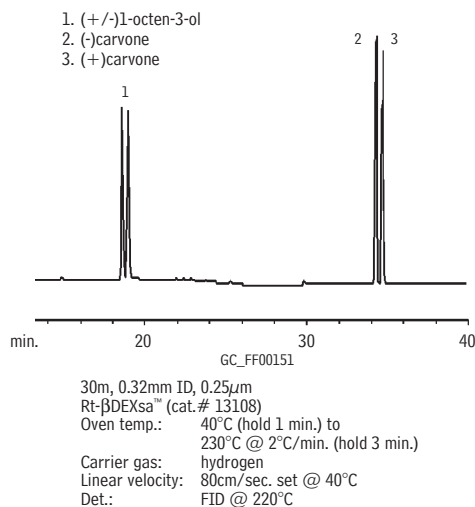
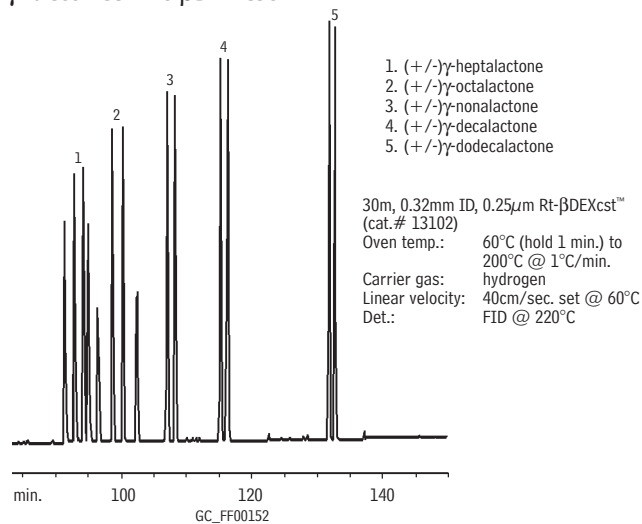
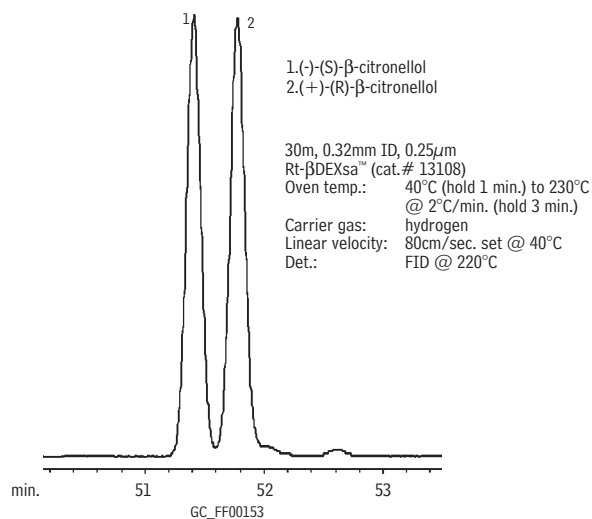
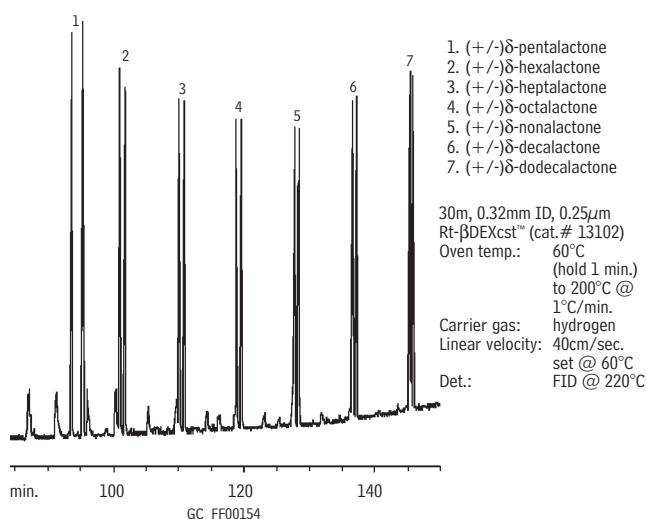
Bergamot Flavor Rt- β DEXse™

GC

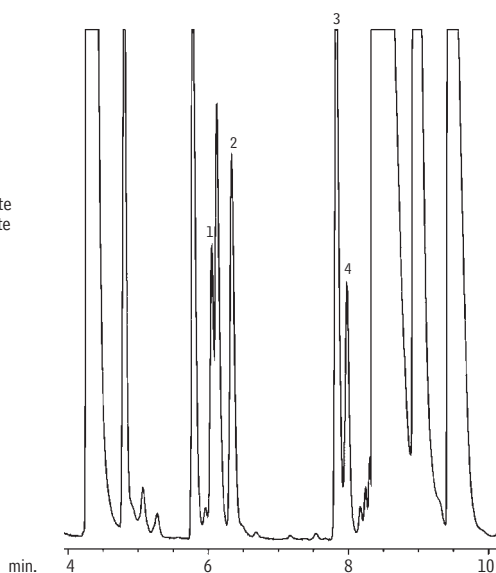
1. (S)-limonene
2. (R)-limonene
3. (R)-linalool
4. (S)-linalool
5. (R)-linalyl acetate
6. (S)-linalyl acetate

30m, 0.32mm ID, 0.25 μ m Rt- β DEXse™ (cat.# 13106)
 Oven temp.: 40°C (hold 1 min.) to 200°C @ 4°C/min.
 Carrier gas: helium, 60cm/sec. set @ 40°C
 Det.: MS @ 220°C



Menthol - Rt- β DEXsp™Irene Isomers - Rt- β DEXcst™1-octen-3-ol and carvone - Rt- β DEXsa™ γ -lactones - Rt- β DEXcst™ β -citronellol - Rt- β DEXsa™ δ -lactones - Rt- δ DEXcst™

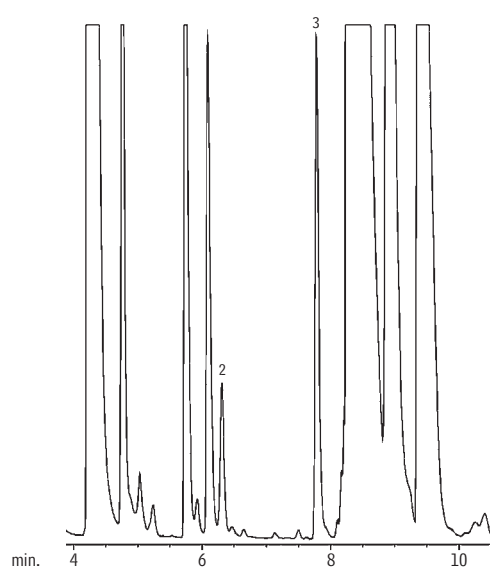
Apple Juice with Added Standards
Rt- β DEXsm™



1. (R)-ethyl 2-methylbutyrate
2. (S)-ethyl 2-methylbutyrate
3. (R)-2-methylbutyrate
4. (S)-2-methylbutyrate

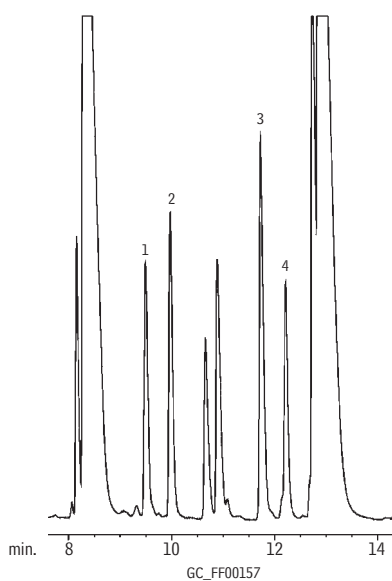
GC_FF00155
30m, 0.32mm ID, 0.25 μ m Rt- β DEXsm™ (cat.# 13104)
On-column conc. (standards): ~50ng

Apple Juice
Rt- β DEXsm™



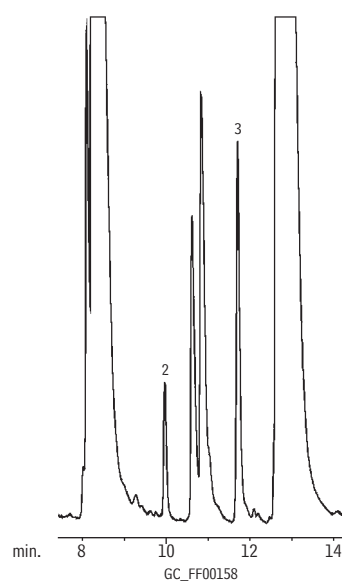
GC_FF00156
30m, 0.32mm ID, 0.25 μ m Rt- β DEXsm™ (cat.# 13104)

Apple Juice with Added Standards
Rt- β DEXse™



GC_FF00157
30m, 0.32mm ID, 0.25 μ m Rt- β DEXse™ (cat.# 13106)
On-column conc. (standards): ~50ng

Apple Juice
Rt- β DEXse™

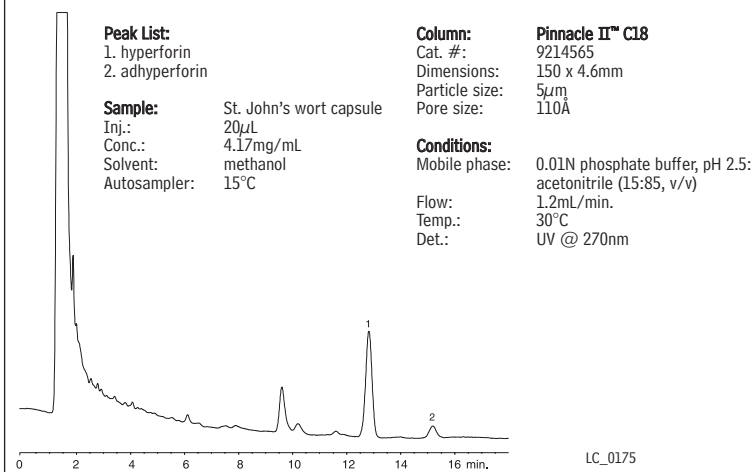


GC_FF00158
30m, 0.32mm ID, 0.25 μ m Rt- β DEXse™ (cat.# 13106)

1.0 μ L split injection.
Oven temp.: 40°C (hold 1 min.) to 220°C @ 2°C/min.
Inj. & det. temp.: 220°C
Carrier gas: hydrogen
Linear velocity: 80cm/sec.

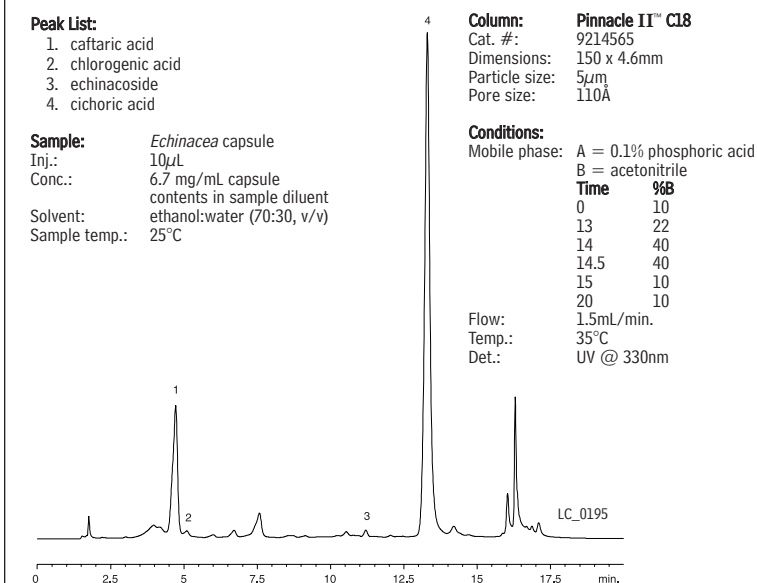
Hyperforin in St. John's Wort Pinnacle II™ C18

HPLC



Phenolics in Echinacea Pinnacle II™ C18

HPLC



Dietary Supplements

Over the past decade, the nutraceutical industry has seen rapid growth as more people add flowers, leaves, roots, and fruits of botanicals to their diets in hope of gaining health benefits.

Herbal products are very complex, often containing hundreds of compounds, and it is not always clear which compounds are responsible for the beneficial properties. Marker compounds—phytochemicals that have been identified and are known to have some relationship to the reported health benefit—can be evaluated qualitatively to identify a raw material or to verify purity. To determine the concentration or strength of a material, quantitative analysis is necessary.

Hyperforin in St. John's Wort

According to the Institute for Nutraceutical Advancement (INA), INA Method 112.001—the HPLC analysis of hyperforin and adhyperforin in St. John's wort—the samples are extracted with methanol in an ultrasonic bath. Chromatographic separation is performed on a C18 reversed phase column with acetonitrile and phosphate buffer as the mobile phase. Analysis of encapsulated St. John's wort using a Pinnacle II™ C18 column shows excellent peak shapes for the active ingredients in this herbal product.

Phenolics in Echinacea

The active compounds in *echinacea* are thought to be caffeic acid derivatives such as caftaric acid, cichoric acid, chlorogenic acid, and echinacoside.

Conclusion

Gas and liquid chromatography are powerful tools for the analysis of foods, flavors, and fragrances. This technical guide describes columns and analytical conditions that will help you achieve more accurate identification and quantitation of target analytes. However, if you have questions, please don't hesitate to contact Restek's technical service by e-mail (support@restekcorp.com) or by phone (extension 4), or contact your Restek representative. We will do everything we can to help you find a solution.

References

- Fennema, O. R. Food Chemistry (1996), 3rd edition.
- Bensing, M. "How Hot is that 'Devil' Sauce?" in Fiery Foods Magazine (1997), Sept/Oct.
- Brandt, Laura. "The Creation and Use of Vanilla", Food Product Design (1996), editorial archives.
- AOAC Official Methods of Analysis (2000), 17th edition, AOAC International.
- Official Methods and Recommended Practices (1998), 5th edition, American Oil Chemists' Society.
- AACC Approved Methods (2000), 10th edition, American Association of Cereal Chemists.

References are not available from Restek.

for more info

Request Applications Note **Analyzing Nutraceutical Products by Liquid and Gas Chromatography** (cat. # 59364).

Flavor and Fragrance Compounds Retention Time Index

Retention time data collected using 60m, 0.25mm ID, 0.25µm Rtx®-1 and Stabilwax® columns.

Oven temp.: 100°C to 260°C @ 4°C/min.; **Carrier gas:** helium; **Linear velocity:** 27.2cm/sec. @ 100°C; **Dead time:** 3.68 min. @ 100°C.

Component	Retention Time (min.)		Component	Retention Time (min.)		Component	Retention Time (min.)	
	Rtx®-1	Stabilwax®		Rtx®-1	Stabilwax®		Rtx®-1	Stabilwax®
isopropyl alcohol	3.66	3.93	2-hexanone	4.41	4.11	5-methylfurfural	5.73	9.64
allyl alcohol	3.67	4.05	ethyl butanoate	4.41	4.18	a-pinene	5.81	4.84
tert-butyl alcohol	3.68	3.89	cyclopentanol	4.42	5.74	benzaldehyde	5.90	8.76
1-propanol	3.70	4.13	cyclopentanone	4.46	4.96	tricyclene	5.91	4.16
3-buten-2-ol	3.71	4.12	2,4-dimethyl-2-pentanol	4.47	4.45	1-heptanol	5.95	7.54
ethyl formate	3.71	3.84	3-hexanol	4.47	4.84	camphene	6.02	4.24
acetone	3.72	3.86	2-hexanol	4.48	5.01	2,6-dimethyl-4-heptanone	6.03	4.81
methyl acetate	3.75	3.86	4-methyl-3-penten-2-one	4.48	4.61	1-octen-3-ol	6.09	7.33
2-butanol	3.76	4.03	hexanal	4.48	4.41	furfuryl acetate	6.09	8.77
propyn-1-ol	3.77	6.26	2,4-dimethyl-3-pentanone	4.49	3.95	3-octanone	6.16	5.35
tert-amyl alcohol	3.79	4.14	pyridine	4.50	4.91	2-octanone	6.20	6.35
isobutyraldehyde	3.79	3.84	propyl propanoate	4.51	4.22	sec-butylbenzene	6.28	5.37
2-methyl-3-buten-2-ol	3.82	4.12	a-angelicalactone	4.51	7.26	tert-butylbenzene	6.32	5.15
methyl ethyl ketone	3.84	3.83	butyl acetate	4.54	4.29	myrcene	6.32	4.53
cis-2-buten-1-ol	3.84	5.01	methyl pentanoate	4.61	4.36	butyl butyrate	6.34	5.02
ethyl acetate	3.86	3.90	furfural	4.64	7.65	b-pinene	6.38	4.40
propyl formate	3.87	3.83	2,2-dimethyl-3-pentanol	4.65	4.63	octanal	6.39	5.73
2-methylfuran	3.88	3.87	2-methyl-1-pentanol	4.65	5.63	2-octanol	6.39	7.00
isobutyl alcohol	3.89	4.72	4-hexen-3-one	4.67	4.88	hexyl acetate	6.49	5.41
methyl propanoate	3.89	4.03	isopropyl butyrate	4.72	4.19	decane	6.58	4.08
3-buten-1-ol	3.91	4.76	furfuryl alcohol	4.74	11.07	2-methylanisole	6.60	6.97
3-methyl-2-butanol	3.92	4.25	2,4-dimethyl-3-pentanol	4.75	4.76	a-phellandrene	6.69	6.13
2-butenal	3.94	4.26	trans-2-hexenal	4.78	5.08	3-methylanisole	6.74	7.39
2-pentanol	3.95	4.42	pinacol	4.79	7.91	4-methylanisole	6.78	7.42
isopropyl acetate	3.96	4.03	ethyl-2-methyl butanoate	4.80	4.26	2-ethyl-1-hexanol	6.85	8.10
1-butanol	3.96	4.57	2-ethyl-1-butanol	4.80	5.72	benzyl alcohol	6.86	16.48
neopentanol	3.99	4.60	trans-2-hexenol	4.82	6.56	3-carene	6.89	4.67
methyl isobutyrate	4.03	4.08	5-methyl-2-hexanone	4.84	4.54	p-cymene	6.91	5.38
2-pentanone	4.03	3.95	1-hexanol	4.92	6.16	a-terpinene	6.93	12.38
isoamyl alcohol	4.04	4.96	3-ethyl-3-pentanol	4.94	4.94	limonene	7.09	4.84
allyl acetate	4.05	4.14	isoamyl acetate	4.98	4.49	salicylaldehyde	7.09	11.93
ethyl acrylate	4.06	4.08	cis-3-hexen-1-ol	4.98	6.58	camphor	7.11	8.77
3-pentanone	4.07	4.08	4-heptanone	4.99	4.45	trans-ocimene	7.13	4.72
pentanal	4.07	4.08	trans-2-hexen-1-ol	5.01	6.81	1,8-cineole	7.16	5.06
tert-butyl acetate	4.09	3.93	anisole	5.06	6.13	eucalyptol	7.16	5.06
pinacolone	4.09	4.00	3-heptanone	5.08	4.62	cis-ocimene	7.21	5.06
propyl acetate	4.10	4.04	1,3-xylene	5.09	4.67	a-methylbenzylalcohol	7.34	18.34
2-ethylfuran	4.10	3.99	1,4-xylene	5.09	4.64	p-cresol	7.45	21.40
2,5-dimethylfuran	4.12	3.98	2-heptanone	5.10	4.85	g-terpinene	7.54	5.26
3-methyl-1-butanol	4.18	4.88	4-heptanol	5.14	5.45	1-octanol	7.55	9.37
3-penten-2-one	4.18	4.45	propyl butyrate	5.16	4.49	2,6-dimethylanisole	7.55	7.16
2-methyl-1-butanol	4.20	4.88	ethyl pentanoate	5.17	4.54	5-nonanone	7.57	6.39
pinacol alcohol	4.20	4.38	cyclohexanone	5.19	5.85	tetrahydrofurfuryl acetate	7.60	9.84
thiophene	4.21	4.16	2-heptanol	5.20	5.63	fenchone	7.68	7.08
methylisobutylketone (MIBK)	4.22	4.15	heptanal	5.21	4.35	linalool oxide	7.81	7.56
methyl butanoate	4.22	4.09	butyl propionate	5.24	4.56	3-nonanone	7.82	6.38
2-methyl-3-pentanone	4.27	4.15	amyl acetate	5.29	4.73	2-nonanone	7.89	7.17
ethyl isobutyrate	4.28	4.03	1,2-xylene	5.30	4.93	methyl benzoate	8.03	10.72
cis-2-penten-1-ol	4.29	5.85	nonane	5.32	3.80	linalool	8.13	9.02
3-methyl-3-pentanol	4.29	4.37	isobutyl isobutyrate	5.34	4.39	2-nonanol	8.15	8.65
1-pentanol	4.30	5.24	methyl hexanoate	5.41	3.81	nonanal	8.16	6.86
3-hexanone	4.30	4.28	tetrahydro-2-fufanmethanol	5.50	8.53	terpinyl acetate	8.18	12.51
3-methyl-2-buten-1-ol	4.32	5.81	d-valerolactone	5.51	9.57	maltol	8.23	18.48
isobutyl acetate	4.34	4.13	cumene	5.62	4.84			
butyrolactone	4.34	7.07	5-methyl-3-heptanone	5.65	4.94			
2-methyl-3-pentanol	4.36	4.59	ethyl amyl ketone	5.65	4.94			

Flavor and Fragrance Compounds Retention Time Index

Retention time data collected using 60m, 0.25mm ID, 0.25µm Rtx®-1 and Stabilwax® columns.

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Component	Retention Time (min.)		Component	Retention Time (min.)		Component	Retention Time (min.)	
	Rtx®-1	Stabilwax®		Rtx®-1	Stabilwax®		Rtx®-1	Stabilwax®
<i>trans</i> -sabinene hydrate	8.37	9.06	r-carvone	11.48	13.28	carvone hydrate	16.25	27.44
2,4-dimethylanisole	8.39	8.45	s-carvone	11.51	13.36	tetradecane	16.38	6.95
2,5-dimethylanisole	8.39	8.42	geraniol	11.74	15.84	coumarin	16.54	29.90
undecane	8.41	4.38	<i>trans</i> -cinnamaldehyde	11.97	20.50	<i>cis</i> -carvyl propionate	16.63	14.68
a-thujone	8.46	15.01	citral b	12.12	13.25	a-ionone	16.88	16.23
methyl octanoate	8.57	6.69	neral	12.12	13.25	<i>trans</i> -cinnamyl acetate	16.88	23.12
b-thujone	8.68	7.63	propyl benzoate	12.16	13.82	ethyl vanillin	17.08	31.44
2,3-dimethylanisole	8.87	9.30	1-decanol	12.36	13.99	isoeugenol	17.09	27.57
citronellal	9.19	7.99	perillaldehyde	12.37	14.52	3-methyl- <i>p</i> -anisaldehyde	17.23	20.08
benzyl acetate	9.31	13.02	citronellyl formate	12.38	10.69	b-caryophyllene	17.32	10.56
menthone	9.42	7.97	<i>trans</i> -menthyl acetate	12.56	9.01	<i>trans</i> -carvyl propionate	17.65	15.76
borneol	9.53	12.52	indole	12.57	29.33	a-methylcinnamic acid	18.15	4.64
ethyl benzoate	9.62	11.74	<i>trans</i> -anethole	12.67	15.41	a-humulene	18.29	12.05
1-nonanol	9.70	11.56	cumin alcohol	12.68	21.88	2,3-dimethylanisaldehyde	18.46	25.74
isoborneol	9.72	11.69	thymol	12.71	23.82	b-ionone	18.57	18.37
menthofuran	9.73	8.14	2-undecanone	12.81	10.45	vanillin acetate	18.93	30.85
isomenthone	9.75	8.57	carvacrol	12.87	24.56	pentadecane	19.34	8.60
neomenthol	9.85	10.22	bornyl acetate	12.88	10.09	valencene	19.40	13.15
a-terpineol	9.91	5.58	<i>trans</i> -cinnamyl alcohol	12.94	26.11	2,5-dimethylanisaldehyde	19.50	21.72
menthol	9.95	11.16	<i>cis</i> -menthyl acetate	13.02	9.62	6-methylcoumarin	20.22	32.66
dihydrocarveol	10.09	13.64	perillyl alcohol	13.02	19.36	carvone acetate	20.50	26.09
terpinen-4-ol	10.11	10.31	tridecane	13.47	5.72	7-methylcoumarin	20.65	32.52
2-decanone	10.14	8.41	2-methylcinnamaldehyde	13.59	19.52	ethyl laurate	21.69	16.17
a-terpinolene	10.32	7.36	triacetin	13.67	21.33	caryophyllene oxide	21.88	19.47
4-allylanisole	10.35	11.75	methyl decanoate	13.69	10.26	hexadecane	22.27	10.64
estragole	10.35	11.75	<i>cis</i> -carvyl acetate	14.09	13.23	cinnamide	22.36	45.53
decanal	10.48	8.51	cumic acid	14.40	34.95	amyl cinnamaldehyde	23.08	25.95
<i>trans</i> -dihydrocarvone	10.59	23.12	g-valerolactone	14.48	10.55	<i>cis</i> - <i>trans</i> -farnesol	24.61	27.48
verbenone	10.67	12.88	citronellyl acetate	14.49	11.81	heptadecane	25.10	12.94
dodecane	10.75	4.90	eugenol	14.55	23.53	<i>trans</i> - <i>trans</i> -farnesol	25.28	28.09
<i>cis</i> -dihydrocarvone	10.80	10.80	thiazole	14.67	5.23	guaiazulene	27.04	28.98
linalyl acetate	10.93	9.36	neryl acetate	14.76	13.08	nootketone	27.69	31.89
b-citronellol	11.06	13.93	<i>trans</i> -carvyl acetate	14.88	14.05	octadecane	27.83	15.40
<i>cis</i> -nerol	11.14	13.82	dihydrocoumarin	14.91	26.02	nonadecane	30.44	17.92
carveol	11.24	16.29	geranyl acetate	15.26	13.08	eicosane	32.94	20.44
benzyl acetone	11.27	16.25	dihydrojasmane	15.34	16.24	heneicosane	35.32	22.91
citral a	11.39	12.13	vanillin	15.34	32.21	docosane	37.62	25.35
geraniol	11.39	12.13	ethyl decanoate	15.69	11.22	tricosane	39.79	27.68
cuminaldehyde	11.43	14.40	2-dodecanone	15.72	12.83	tetracosane	42.02	29.95
pulegone	11.43	11.46	<i>cis</i> -jasmane	15.75	18.34	hexacosane	47.40	34.26
<i>p</i> -anisaldehyde	11.47	20.15	<i>trans</i> -cinnamyl acid	16.07	37.16			

rtx®-1 F&F gc columns

for flavor and fragrance compounds

- Specifically tailored to meet the demanding selectivity criteria of the flavor and fragrance industry.
- Excellent thermal stability and column lifetimes.
- Stringent QA ensures column-to-column reproducibility.

See **page 30** for product listing.

