High-Resolution GC Analyses of Fatty Acid Methyl Esters (FAMEs)

Fatty acid methyl esters (FAMEs) analysis is an important tool both for characterizing fats and oils and for determining the total fat content in foods. Fats can be extracted from a matrix using a nonpolar solvent and saponified to produce salts of the free fatty acids. After derivatizing the free acids to form methyl esters, the mixture can readily be analyzed by gas chromatography (GC) due to the volatility and thermal stability of the FAMEs. Gas chromatography has become an important technique in fats and oils analysis because accurate results can be obtained for complex as well as simple sample matrices.

FAMEs analyses were among the first applications for gas chromatography, so many of the GC methods originally written for analysis of fats and oils described packed column technology. However, capillary columns offer significant advantages, including more efficient separations. When analyzing fats and oils with complex fatty acid profiles such as the *cis* and *trans* forms of polyunsaturated fatty acids, higher efficiencies are needed to resolve the individual components. Capillary columns with Carbowax-type (polyethylene glycol) stationary phases are typically used for analyses of saturated and unsaturated fatty acid methyl esters (Figures 1 and 2), and biscyanopropyl phases are used to resolve *cis* and *trans* isomers of polyunsaturated components (Figure 3).

Creating FAMEs

Lipids are normally extracted from matrices using a nonpolar solvent such as ether and saponified to produce the free fatty acid salts. The fatty acid salts then are derivatized to form the fatty acid methyl esters, to increase volatility, improve peak symmetry, and decrease sample activity, thus providing more accurate analytical data. The official methods of the Association of Official Agriculture Chemists (AOAC International) [1] and the American Oil Chemists Society (AOCS) [2] contain procedures for the derivatization reaction, as does the European Pharmacopoeia [3]. In general, the glycerides are saponified by refluxing with methanolic sodium hydroxide. The esterification is effected with a reagent such as boron trifluoride in methanol, and the FAMEs are extracted with a nonpolar solvent (e.g., heptane) for analysis by GC.

Several groups of researchers have proposed simplified procedures for creating the methyl esters. For example, lipids can be transmethylated in situ. This option combines all of the conventional steps, except the drying and post-reaction workup, into one step. [4] For some samples, trimethylsulfonium hydroxide (TMSH), sodium methoxide, or methanolic hydrochloric acid, which are alternative derivatization reagents, can be used for transesterification. A major advantage of this approach is that the derivatization can be performed in a single, fast reaction step. [5,6,7]

Figure 1: A FAMEWAX column provides fast, efficient separations of FAMEs in a marine oil-based standard.

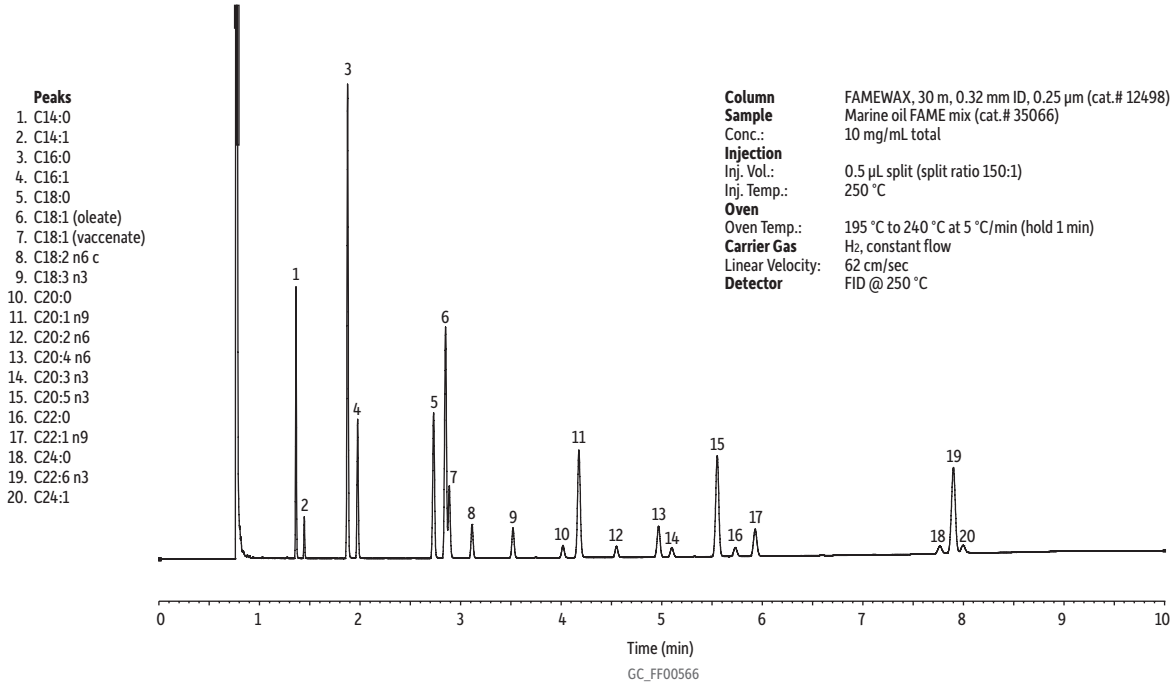


Figure 2: Rapid, excellent resolution of ocean nutrition sample FAMEs, using a FAMEWAX column.

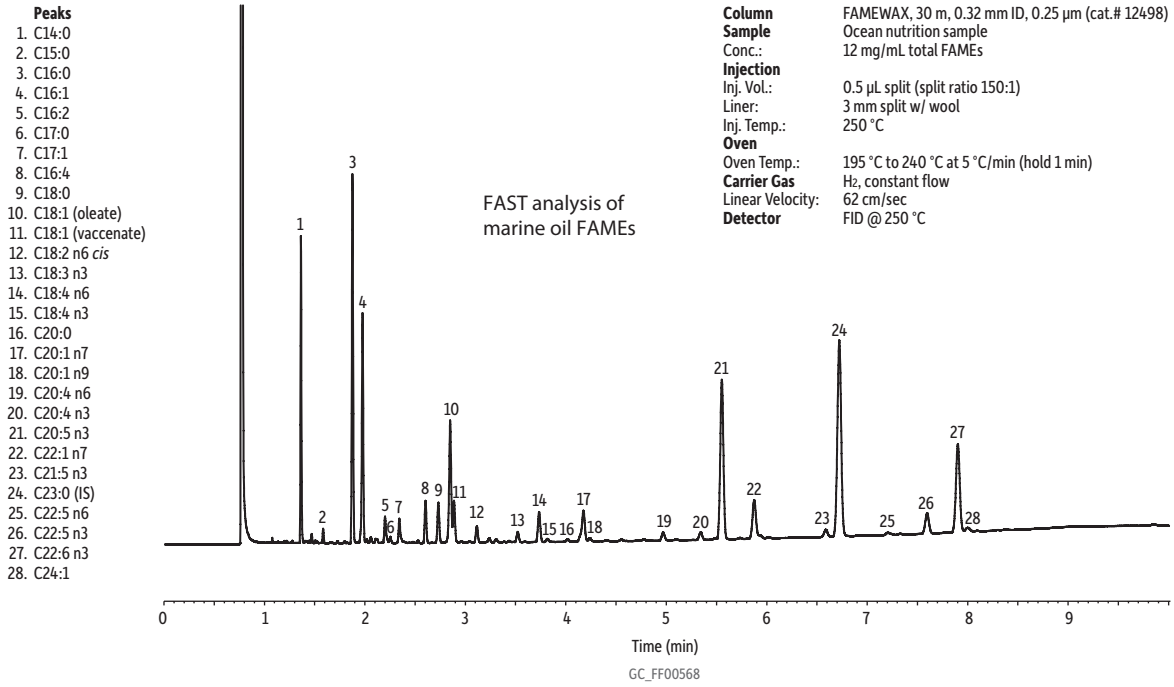
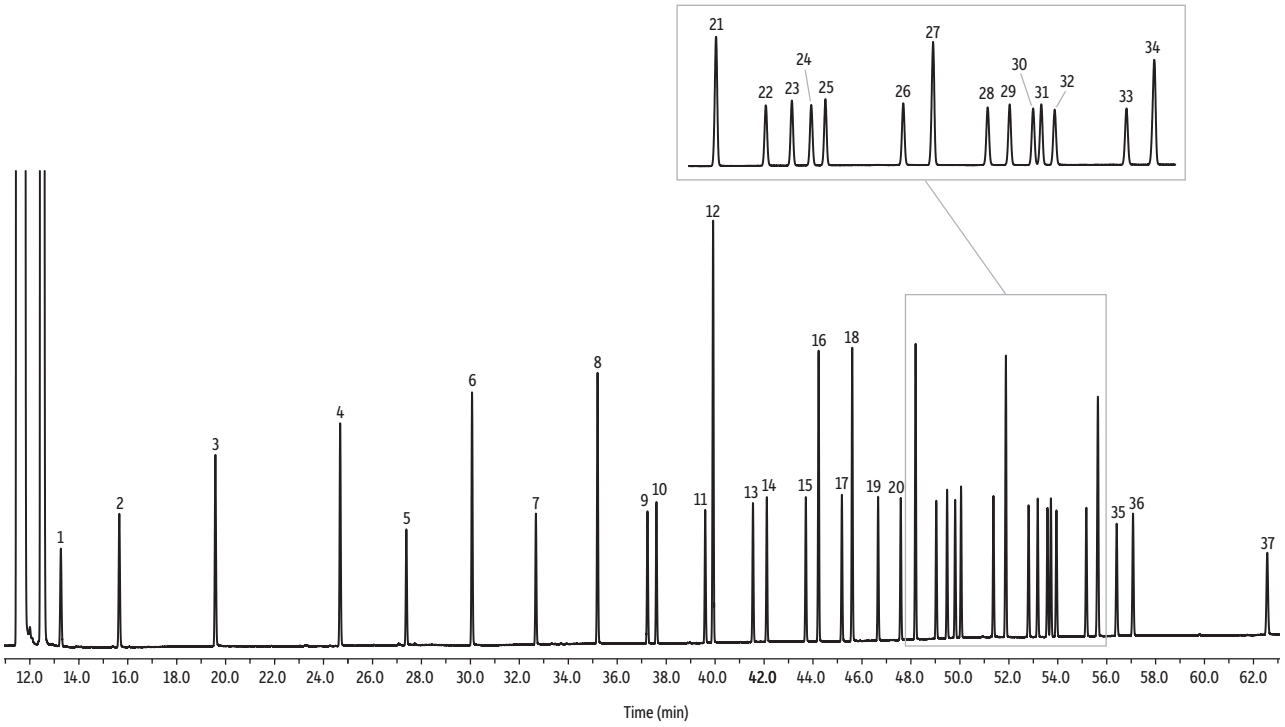


Figure 3: Near-complete resolution of a 37 FAME mix on an Rt-2560 column.



Peaks	t_R (min)	Conc. (µg/mL)	Structural Nomenclature
1. Methyl butyrate	13.16	40	C4:0
2. Methyl caproate	15.53	40	C6:0
3. Methyl octanoate	19.43	40	C8:0
4. Methyl decanoate	24.50	40	C10:0
5. Methyl undecanoate	27.20	20	C11:0
6. Methyl dodecanoate	29.87	40	C12:0
7. Methyl tridecanoate	32.47	20	C13:0
8. Methyl myristate	34.97	40	C14:0
9. Methyl myristoleate	37.01	20	C14:1 (c9)
10. Methyl pentadecanoate	37.37	20	C15:0
11. Methyl pentadecenoate	39.36	20	C15:1 (c10)
12. Methyl palmitate	39.68	60	C16:0
13. Methyl palmitoleate	41.30	20	C16:1 (c9)
14. Methyl heptadecanoate	41.86	20	C17:0
15. Methyl heptadecenoate	43.45	20	C17:1 (c10)
16. Methyl stearate	43.97	40	C18:0
17. Methyl octadecenoate	44.92	20	C18:1 (t9)
18. Methyl oleate	45.34	40	C18:1 (c9)
19. Methyl linolelaidate	46.39	20	C18:2 (t9,t12)
20. Methyl linoleate	47.32	20	C18:2 (c9,c12)
21. Methyl arachidate	47.92	40	C20:0
22. Methyl linolenate	48.77	20	C18:3 (c6,c9,c12)
23. Methyl eicosenoate	49.20	20	C20:1 (c11)
24. Methyl linolenate	49.54	20	C18:3 (c9,c12,c15)
25. Methyl heneicosanoate	49.78	20	C21:0
26. Methyl eicosadienoate	51.09	20	C20:2 (c11,c14)
27. Methyl behenate	51.60	40	C22:0
28. Methyl eicosatrienoate	52.52	20	C20:3 (c8,c11,c14)
29. Methyl erucate	52.88	20	C22:1 (c13)
30. Methyl eicosatrienoate	53.28	20	C20:3 (c11,c14,c17)
31. Methyl tricosanoate	53.42	20	C23:0
32. Methyl arachidonate	53.65	20	C20:4 (c5,c8,c11,c14)
33. Methyl docosadienoate	54.85	20	C22:2 (c13,c16)
34. Methyl lignocerate	55.32	40	C24:0
35. Methyl eicosapentaenoate	56.09	20	C20:5 (c5,c8,c11,c14,c17)
36. Methyl nervonate	56.74	20	C24:1 (C15)
37. Methyl docosahexaenoate	62.17	20	C22:6 (c4,c7,c10,c13,c16,c19)

Column	Rt-2560, 100 m, 0.25 mm ID, 0.20 µm (cat.# 13198)
Sample	Food industry FAME mix (cat.# 35077)
Diluent:	Hexane/dichloromethane
Conc:	1,000 µg/mL
Injection	
Inj. Vol.:	1 µL split (split ratio 20:1)
Liner:	Premium 4 mm Precision liner w/wool (cat.# 23305.1)
Inj. Temp:	225 °C
Oven	
Oven Temp.:	100 °C (hold 4 min) to 240 °C at 3 °C/min (hold 15 min)
Carrier Gas	He, constant flow
Flow Rate:	1.0 mL/min
Detector	FID @ 285 °C
Make-up Gas Flow Rate:	45 mL/min
Make-up Gas Type:	N_2
Hydrogen flow:	30 mL/min
Air flow:	300 mL/min
Data Rate:	20 Hz
Instrument	Agilent 7890A GC

Analyzing Polyunsaturated FAMEs

The FAMEWAX polyethylene glycol stationary phase is specially tested with a polyunsaturated FAMEs mix to ensure resolution of the omega-3 and omega-6 fatty acids of interest. FAMEs such as methyl eicosapentenoate (C20:5) and methyl docosahexaenoate (C22:6), found in nutraceutical ingredients and products such as marine oils, also are resolved. FAMEWAX columns offer excellent resolution of polyunsaturated FAMEs with significantly reduced analysis times compared to traditional Carbowax stationary phases. In fact, analysis times of less than 10 minutes are possible! Figures 1 and 2 show analyses of a marine oil FAME standard and ocean nutrition sample, respectively. Both analyses are characterized by fast, effective resolution and sharp, symmetric peaks.

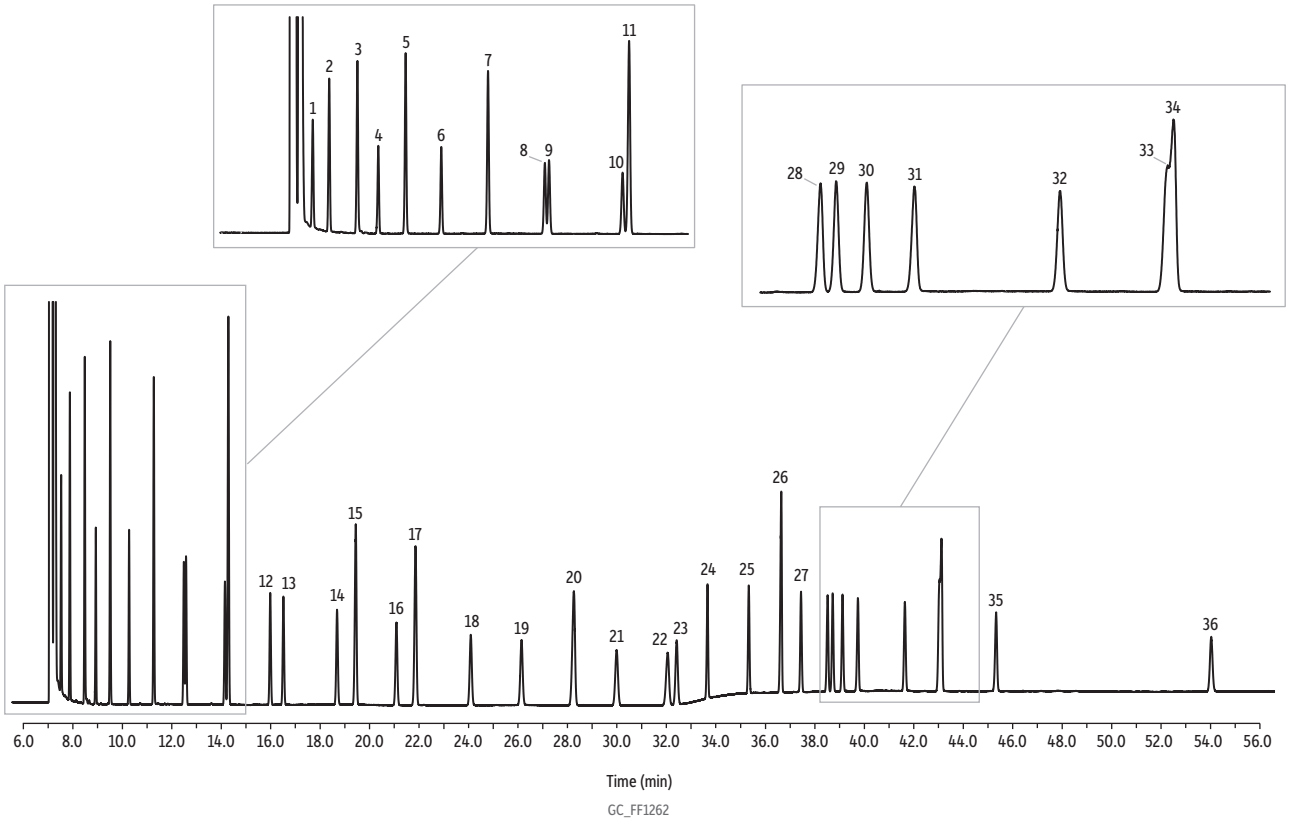
Like FAMEWAX columns, Stabilwax columns and Rtx-Wax columns provide excellent resolution of FAMEs derived from either plant or animal sources. When polyunsaturated FAMEs are analyzed on one of these Carbowax-type capillary columns, analysis times of 35-50 minutes are generally required to fully resolve the C21:5 FAME from the C23:0 internal standard, and the C24:0 FAME from C22:6.

Resolving *cis* and *trans* Isomers

Individual *cis* and *trans* isomers are resolved on a 100-meter Rt-2560 column, making this the column of choice for analyzing partially hydrogenated fats. The highly polar biscyanopropyl phase gives the selectivity needed for resolving FAME isomers, such as the *cis* and *trans* forms of C18:1. The *trans* isomers elute before the *cis* isomers on this phase, opposite of the elution order on Carbowax-based phases such as FAMEWAX or Rtx-Wax. Figure 3 shows the chromatographic separation of 37 FAMEs typically encountered in vegetable, animal, or marine fats and oils using an Rt-2560 column.

AOAC method 996.06 [1] describes the determination of total fat content based on the fatty acid content after conversion to methyl esters. This is the specified method for determining total fat content for nutritional labeling purposes. After quantifying the total FAMEs present in the derivatized sample, the amount of fat (as triglycerides) in the sample is calculated based on initial sample weight. The 100-meter Rt-2560 column meets the requirements of this procedure (Figure 4). This column also allows quantification of the total *trans* content.

Figure 4: Use this food industry FAME mix to standardize fat-by-fatty acid composition methods, such as AOAC 996.06.



GC_FF1262

Peaks	t_R (min)	Conc. (µg/mL)	Structural Nomenclature
1. Methyl caproate	7.52	40	C6:0
2. Methyl octanoate	7.88	40	C8:0
3. Methyl decanoate	8.48	40	C10:0
4. Methyl undecanoate	8.93	20	C11:0
5. Methyl dodecanoate	9.51	40	C12:0
6. Methyl tridecanoate	10.27	20	C13:0
7. Methyl myristate	11.27	40	C14:0
8. Methyl myristoleate	12.48	20	C14:1 (c9)
9. Methyl pentadecanoate	12.57	20	C15:0
10. Methyl pentadecenoate	14.15	20	C15:1 (C10)
11. Methyl palmitate	14.28	60	C16:0
12. Methyl palmitoleate	15.98	20	C16:1 (c9)
13. Methyl heptadecanoate	16.51	20	C17:0
14. Methyl heptadecenoate	18.68	20	C17:1 (c10)
15. Methyl stearate	19.43	40	C18:0
16. Methyl octadecenoate	21.08	20	C18:1 (t9)
17. Methyl oleate	21.85	40	C18:1 (c9)
18. Methyl linolelaidate	24.09	20	C18:2 (t9,t12)
19. Methyl linoleate	26.14	20	C18:2 (c9,c12)
20. Methyl arachidate	28.25	40	C20:0
21. Methyl linolenate	29.98	20	C18:3 (c6,c9,c12)
22. Methyl eicosenoate	32.05	20	C20:1 (c11)
23. Methyl linolenate	32.41	20	C18:3 (c9,c12,c15)
24. Methyl heneicosanoate	33.66	20	C21:0
25. Methyl eicosadienoate	35.33	20	C20:2 (c11,c14)
26. Methyl behenate	36.64	40	C22:0
27. Methyl eicosatrienoate	37.44	20	C20:3 (c8,c11,c14)
28. Methyl erucate	38.51	20	C22:1 (c13)
29. Methyl eicosatrienoate	38.72	20	C20:3 (c11,c14,c17)
30. Methyl arachidonate	39.12	20	C20:4 (c5,c8,c11,c14,c17)
31. Methyl tricosanoate	39.74	20	C23:0
32. Methyl docosadienoate	41.64	20	C22:2 (c13,c16)
33. Methyl eicosapentaenoate	43.07	20	C20:5 (c5,c8,c11,c14,c17)
34. Methyl lignocerate	43.11	40	C24:0
35. Methyl nervonate	45.33	20	C24:1 (c15)
36. Methyl docosahexaenoate	54.02	20	C22:6 (c4,c7,c10,c13,c16,c19)

Column	Rt-2560, 100 m, 0.25 mm ID, 0.20 µm (cat.# 13198)
Sample	Food industry FAME mix (cat.# 35077)
Diluent:	Hexane/dichloromethane
Conc.:	1,000 µg/mL
Injection	
Inj. Vol.:	1 µL split (split ratio 20:1)
Liner:	Premium 4 mm Precision liner w/wool (cat.# 23305.1)
Inj. Temp.:	235 °C
Oven	
Oven Temp.:	180 °C (hold 32 min) to 215 °C at 20 °C/min (hold 31.25 min)
Carrier Gas	He, constant flow
Flow Rate:	2.0 mL/min
Detector	FID @ 325 °C
Make-up Gas Flow Rate:	45 mL/min
Make-up Gas Type:	N_2
Hydrogen flow:	30 mL/min
Air flow:	300 mL/min
Data Rate:	20 Hz
Instrument	Agilent 7890A GC
Notes	C4:0 Methyl butyrate (623-42-7) elutes in the solvent front.

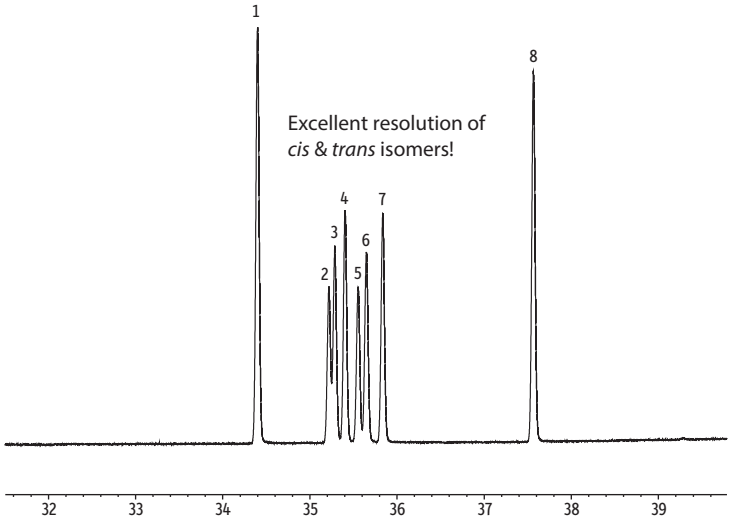
To calibrate the GC system for assays of this type, use a FAME mixture such as our 37-component food industry FAME mix (Figures 3 and 4), or our 28-component food industry FAME mix. These standards include a gravimetric certificate of analysis to help ensure accurate quantification. To ensure correct identifications of the individual *cis* and *trans* isomers, use our *cis*/*trans* FAMEs mix as shown in Figure 5, or our *trans* fat mix shown in Figure 6.

Rtx-2330, a 90% biscyanopropyl phase, also resolves *cis* and *trans* FAME isomers. These columns are slightly less polar than Rt-2560 columns. Figure 7 shows the analysis of an animal-based fat using an Rtx-2330 column. As on Rt-2560 columns, the *trans* forms of the FAMEs elute before the *cis* forms.

Analyzing Botanical Products

Gas chromatography can be used to analyze fatty acid marker compounds in some botanical products. Both Rtx-Wax and Stabilwax capillary columns provide the efficiency and selectivity needed to perform analysis and allow accurate identification of the individual fatty acids in products such as saw palmetto oil, olive oil, and palm oil (Figures 8-10).

Figure 5: Resolve *cis* and *trans* isomers of unsaturated FAMEs on an Rt-2560 column.



Peaks	t_R (min)	Conc. mg/mL)	Structural Nomenclature
1. Methyl stearate	34.402	2.0	C18:0
2. Methyl petroselaidate	35.220	0.8	C18:1 (*trans*-6)
3. Methyl elaidate	35.288	1.0	C18:1 (*trans*-9)
4. Methyl *trans*-vaccenate	35.405	1.2	C18:1 (*trans*-11)
5. Methyl petroselinate	35.555	0.8	C18:1 (*cis*-6)
6. Methyl oleate	35.650	1.0	C18:1 (*cis*-9)
7. Methyl vaccenate	35.838	1.2	C18:1 (*cis*-11)
8. Methyl linoleate	37.567	2.0	C18:2 (*cis*-9,12)

Column	Rt-2560, 100 m, 0.25 mm ID, 0.20 µm (cat.# 13198)
Sample	*cis*/*trans* FAME mix (cat.# 35079)
Diluent:	Methylene chloride
Injection	
Inj. Vol.:	1 µL split (split ratio 200:1)
Liner:	Topaz 4 mm ID straight inlet liner w/ wool (cat.# 23300)
Inj. Temp.:	240 °C
Oven	
Oven Temp.:	100 °C (hold 4 min) to 240 °C at 3 °C/min (hold 10 min)
Carrier Gas	H_2, constant flow
Flow Rate:	2.2 mL/min
Detector	FID @ 250 °C
Instrument	Agilent 7890A GC

Figure 6: Rt-2560 columns provide excellent separation of *trans* fats.

Peaks	t_R (min)	Conc. (wt.%)	Structural Nomenclature
1. Methyl myristelaidate	21.806	6	C14:1 (*trans*-9)
2. Methyl *trans*-pentandecen-10-oate	24.832	6	C15:1 (*trans*-10)
3. Methyl palmitelaidate	27.605	6	C16:1 (*trans*-9)
4. Methyl *trans*-heptadecen-10-oate	30.660	6	C17:1 (*trans*-10)
5. Methyl petroselaidate	33.407	4	C18:1 (*trans*-6)
6. Methyl elaidate	33.513	16	C18:1 (*trans*-9)
7. Methyl *trans*-vaccenate	33.679	12	C18:1 (*trans*-11)
8. Methyl linoelaidate	35.583	6	C18:2 (*trans*-9,12)
9. Methyl *trans*-nonadecen-7-oate	36.303	6	C19:1 (*trans*-7)
10. Methyl *trans*-nonadecen-10-oate	36.455	12	C19:1 (*trans*-10)
11. Methyl *trans*-eicosan-11-oate	39.270	6	C20:1 (*trans*-11)
12. Methyl brassidate	44.764	6	C21:1 (*trans*-13)
13. Methyl ricinelaidate	56.987	8	C18:1 (*trans*-9; OH-12)

Column Rt-2560, 100 m, 0.25 mm ID, 0.20 µm (cat.# 13198)
Sample *trans* Fat reference standard (cat.# 35629)
Diluent: Hexane
Injection
Inj. Vol.: 1 µL split (split ratio 200:1)
Liner: Topaz 4.0 mm ID straight inlet liner w/wool (cat.# 23300)
Inj. Temp.: 250 °C
Oven
Oven Temp.: 120 °C (hold 1 min) to 250 °C at 2 °C/min (hold 4 min)
Carrier Gas H_2, constant flow
Flow Rate: 2 mL/min
Detector FID @ 250 °C
Instrument Agilent 7890A GC

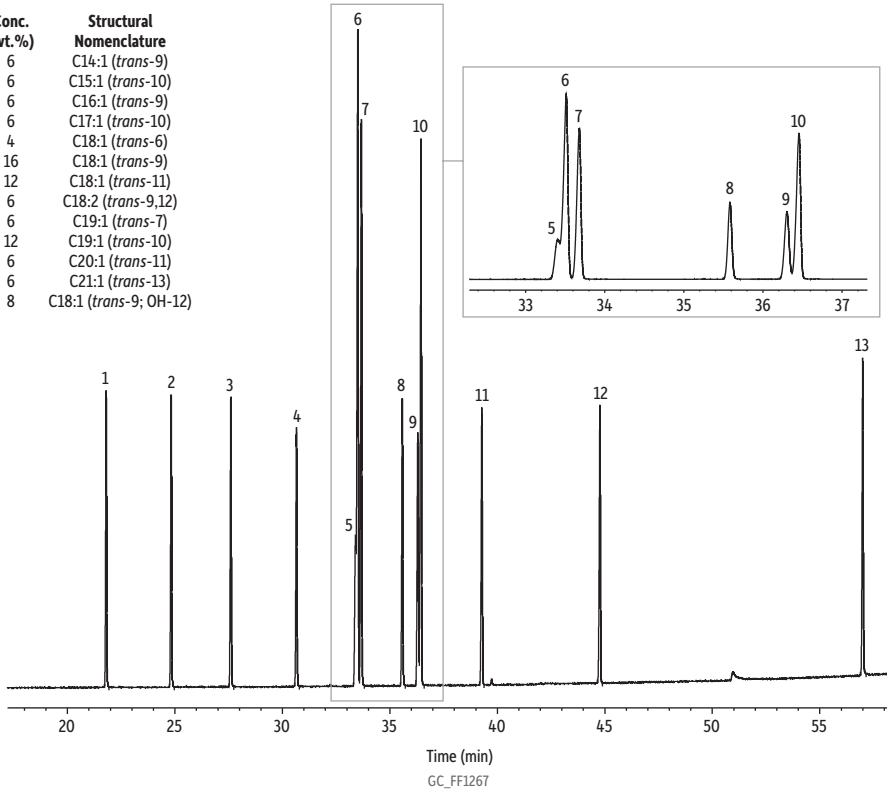
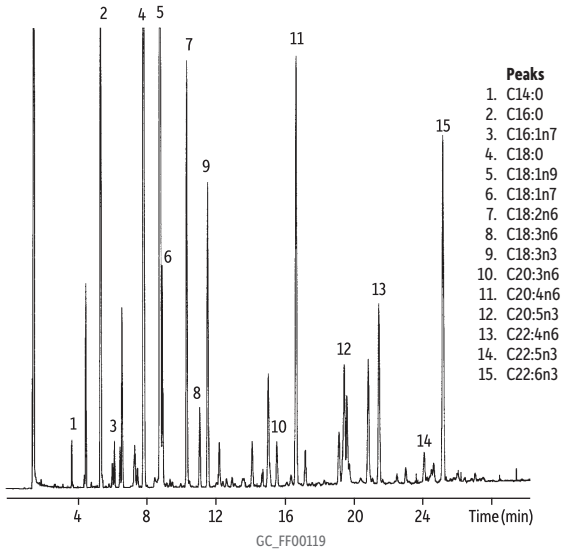


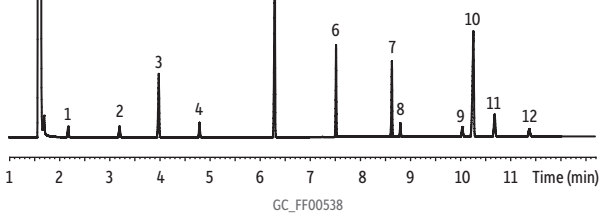
Figure 7: Animal fat-based FAMEs resolved, using an Rtx-2330 column.



Column Rtx-2330, 30 m, 0.32 mm ID, 0.20 µm (cat.# 10724)
Sample PUFA 2 mix
Injection
Inj. Vol.: 0.1 µL split (split ratio 20:1)
Inj. Temp.: 260 °C
Oven
Oven Temp: 160 °C to 250 °C at 2 °C/min (hold 10 min)
Carrier Gas H_2, constant pressure
Linear Velocity: 40 cm/sec
Detector FID @ 260 °C
Notes FID sensitivity: 8 x 10^{-11} AFS

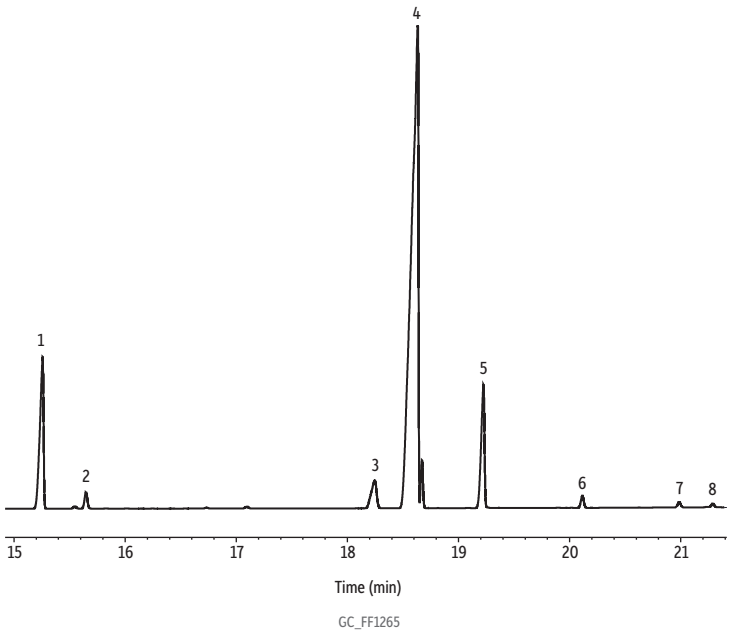
Figure 8: Saw palmetto FAMEs resolved on an Rtx-WAX column.

Peak List	Conc. (mg/mL)
1. methyl caproate (C6:0)	0.4
2. methyl caprylate (C8:0)	0.4
3. methyl nonanoate (C9:0)	2.0
4. methyl caprate (C10:0)	0.4
5. methyl laurate (C12:0)	5.0
6. methyl myristate (C14:0)	2.0
7. methyl palmitate (C16:0)	2.0
8. methyl palmitoleate (C16:1)	0.4
9. methyl stearate (C18:0)	0.4
10. methyl oleate (C18:1)	5.0
11. methyl linoleate (C18:2)	1.0
12. methyl linolenate (C18:3)	0.4



Column **30m, 0.25mm, 0.25µm Rtx-Wax (cat.# 12423)**
Sample **1µL split injection of saw palmetto standard**
Conc.: **see peak list**
Oven
Oven Temp: 120°C (hold 3 min.) to 220°C at 20°C/min. (hold 12 min.)
Inj./det. temp.: **250°C/300°C**
Carrier Gas helium
Linear velocity: **1mL/min. (34 cm/sec.)**
Split ratio: **100:1**

Figure 9: Olive oil FAMEs on a Stabilwax column.

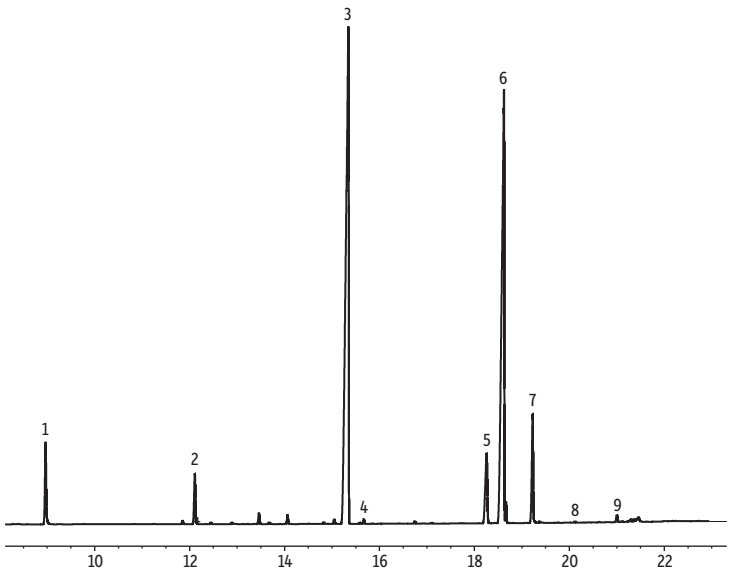


GC_FF1265

Peaks	t_R (min)	Conc. (wt.%)	Structural Nomenclature
1. Methyl palmitate	15.256	11.9	C16:0
2. Methyl palmitoleate	15.646	1.0	C16:1 (*cis*-9)
3. Methyl stearate	18.244	3.2	C18:0
4. Methyl oleate	18.631	73.2	C18:1 (*cis*-9)
5. Methyl linoleate	19.223	8.9	C18:2 (*cis*-9,12)
6. Methyl linolenate	20.114	0.8	C18:3 (*cis*-9,12,15)
7. Methyl arachidate	20.985	0.5	C20:0
8. Methyl eicosenoate	21.287	0.4	C20:1 (*cis*-11)

Column	Stabilwax, 60 m, 0.25 mm ID, 0.25 µm (cat.# 10626)
Sample	Olive oil reference standard (Sigma-Aldrich #47118)
Diluent:	Hexane
Injection	
Inj. Vol.:	1 µL split (split ratio 100:1)
Liner:	Topaz 4 mm ID straight inlet liner w/ wool (cat.# 23300)
Inj. Temp.:	225 °C
Oven	
Oven Temp.:	120 °C (hold 0.5 min) to 250 °C at 6 °C/min (hold 15 min)
Carrier Gas	H_2, constant flow
Flow Rate:	2 mL/min
Detector	FID @ 250 °C
Instrument	Agilent 7890A GC
Notes	The sample was prepared using methanolic HCl.

Figure 10: Palm oil FAMEs on a Stabilwax column.



GC_FF1266

Peaks	t_R (min)	Conc. (wt.%)	Structural Nomenclature
1. Methyl laurate	8.963	3.0	C12:0
2. Methyl myristate	12.106	2.0	C14:0
3. Methyl palmitate	15.344	50.2	C16:0
4. Methyl palmitoleate	15.668	1.5	C16:1 (*cis*-9)
5. Methyl stearate	18.254	4.4	C18:0
6. Methyl oleate	18.620	34.1	C18:1 (*cis*-9)
7. Methyl linoleate	19.224	4.5	C18:2 (*cis*-9,12)
8. Methyl linolenate	20.118	0.1	C18:3 (*cis*-9,12,15)
9. Methyl arachidate	21.001	0.2	C20:0

Column	Stabilwax, 60 m, 0.25 mm ID, 0.25 µm (cat.# 10626)
Sample	Palm oil standard (Supelco #46962)
Diluent:	Hexane
Injection	
Inj. Vol.:	1 µL split (split ratio 100:1)
Liner:	Topaz 4 mm ID straight inlet liner w/ wool (cat.# 23300)
Inj. Temp.:	225 °C
Oven	
Oven Temp.:	120 °C (hold 0.5 min) to 250 °C at 6 °C/min (hold 15 min)
Carrier Gas	H_2, constant flow
Flow Rate:	2 mL/min
Detector	FID @ 250 °C
Instrument	Agilent 7890A GC
Notes	The sample was prepared using methanolic HCl.

Summary

Capillary GC is especially useful for determining total fat content, *trans* fat content, and total omega-3 polyunsaturated fatty acid content in foods. The choice of capillary column depends on the information required. For polyunsaturated FAMEs analysis, a FAMEWAX column allows fast, accurate quantification. A more polar Rt-2560 column is the column of choice when determining the total fat content, or the amount of *trans* fat, in an ingredient or end product.

Whatever your fatty acid analysis requirements, Restek can provide the consistent-performance analytical columns and reference mixes that will help you to accurately characterize your materials.

Composition of each mixture listed as a weight/weight % basis (minimum 50 mg/ampul)

	Mix Cat. #																		
Compound Name	**FAME #1 35010**	**FAME #2 35011**	**FAME #3 35012**	**FAME #4 35013**	**FAME #5 35014**	**FAME #6 35015**	**FAME #7 35016**	**FAME #8 35017**	**FAME #9 35018**	**FAME #12 35021**	**FAME #13 35034**	**FAME #14 35035**	**FAME #15 35036**	**FAME #16 35022**	**FAME #17 35023**	**FAME #18 35024**	**FAME #19 35025**	**FAME #20 35026**	**FAME #21 35027**
Methyl caproate (6:0)		20.0					20.0												
Methyl heptanoate (7:0)							20.0												
Methyl caprylate (8:0)		20.0	20.0				20.0											7.0	
Methyl nonanoate (9:0)							20.0												
Methyl caprate (10:0)		20.0	20.0				20.0											5.0	
Methyl undecanoate (11:0)								20.0											
Methyl laurate (12:0)		20.0	20.0					20.0										48.0	
Methyl tridecanoate (13:0)								20.0		20.0									
Methyl myristate (14:0)		20.0	20.0					20.0				0.1				1.0		15.0	2.0
Methyl pentadecanoate (15:0								20.0		20.0									
Methyl palmitate (16:0)	20.0		20.0	20.0					20.0		3.0	26.3	10.0	6.0	7.0	4.0	11.0	7.0	30.0
Methyl palmitoleate (16:1)					20.0						1.0	0.4							3.0
Methyl heptadecanoate (17:0)									20.0	20.0		0.3							
Methyl stearate (18:0)	20.0			20.0					20.0		2.0	33.7	3.0	3.0	5.0	3.0	3.0	3.0	14.0
Methyl oleate (18:1)	20.0				20.0						20.0	34.3	50.0	35.0	18.0	45.0	80.0	12.0	41.0
Methyl linoleate (18:2)	20.0										15.0	3.1	30.0	50.0	36.0	15.0	6.0	3.0	7.0
Methyl linolenate (18:3)	20.0										10.0	0.2		3.0	34.0	3.0			3.0
Methyl nonadecanoate (19:0)									20.0	20.0									
Methyl arachidate (20:0)				20.0		20.0			20.0		1.0	1.3	1.5	3.0		3.0			
Methyl eicosenoate (20:1)					20.0	20.0					10.0	0.1	1.5						
Methyl eicosadienoate (20:2)						20.0					2.0								
Methyl homo gamma linolenate (20:3)						20.0													
Methyl arachidonate (20:4)						20.0													
Methyl heneicosanoate (21:0)										20.0									
Methyl behenate (22:0)				2.0							1.0	0.2	3.0			3.0			
Methyl erucate (22:1)					20.0						30.0					20.0			
Methyl docosadienoate (22:2)											20.0								
Methyl lignocerate (24:0)				20.0							1.0		1.0			3.0			
Methyl nervonate (24:1)					20.0						2.0								

References

[1] M.M. Mossoba, J.K.G. Kramer, P. Delmonte, M.P. Yurawecz, J.I. Rader, Official methods for the determination of *trans* fat, AOCS Press, 2003. http://www.aoac.org/aoac_prod_imis/aoac/AOAC_Member/BS/10650.aspx.

[2] AOCS Committee, Official methods and recommended practices of the AOCS, 7th edition, AOCS Press, 2017. https://www.aocs.org/store/shop-aocs/shop-aocs?productId=70978091.

[3] European pharmacopoeia (Ph. Eur.) 9th edition, European Pharmacopoeia, 2017. Book, online, PDF. https://www.edqm.eu/en/european-pharmacopoeia-ph-eur-9th-edition.

[4] K. Liu, Preparation of fatty acid methyl esters for gas-chromatographic analysis of lipids in biological materials, J Am Oil Chem Soc 71 (11) (1994) 1179-1187. https://onlinelibrary.wiley.com/doi/abs/10.1007/BF02540534.

[5] K-D Müller, H.P. Nalik, E.N. Schmid, H. Husmann, G. Schomburg, Fast identification of mycobacterium species by GC analysis with trimethylsulfonium hydroxide (TMSH) for transesterification, J Sep Sci, 16 (3) (1993) 161-165. https://onlinelibrary.wiley.com/doi/abs/10.1002/jhrc.1240160306.

[6] K. Ichihara, Y. Fukubayashi, Preparation of fatty acid methyl esters for gas-liquid chromatography, J Lipid Res, 1 (3) (2010) 635–640. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2817593.

[7] K. iIchihara, C. Kohsaka, N. Tomari, T. Kiyono, J. Wada, K. Hirooka, Y. Yamamoto, Fatty acid analysis of triacylglycerols: Preparation of fatty acid methyl esters for gas chromatography Anal Biochem 495 (2016) 6-8. https://www.sciencedirect.com/science/article/pii/S0003269715005357

Rtx-Wax Columns (fused silica)
polar phase; Crossbond polyethylene glycol

ID	df	temp. limits*	15-Meter cat.#	30-Meter cat.#	60-Meter cat.#
0.25 mm	0.25 µm	20 to 250 °C	12420	12423	12426
	0.50 µm	20 to 250 °C	12435	12438	12441
0.32 mm	0.25 µm	20 to 250 °C		12424	12427
	0.50 µm	20 to 250 °C	12436	12439	12442
	1.00 µm	20 to 240/250 °C	12451	12454	12457
0.53 mm	0.25 µm	20 to 250 °C		12425	
	0.50 µm	20 to 250 °C		12440	
	1.00 µm	20 to 240/250 °C	12452	12455	12458

*Maximum temperatures listed are for shorter length columns. Longer columns may have a different maximum temperature.

Stabilwax Columns (fused silica)
polar phase; Crossbond polyethylene glycol

ID	df	temp. limits	15-Meter cat.#	30-Meter cat.#	60-Meter cat.#
0.25 mm	0.10 µm	40 to 250/260 °C	10605	10608	10611
	0.25 µm	40 to 250/260 °C	10620	10623	10626
	0.50 µm	40 to 250/260 °C	10635	10638	10641
0.32 mm	0.25 µm	40 to 250/260 °C	10621	10624	10627
	0.50 µm	40 to 250/260 °C	10636	10639	10642
	1.00 µm	40 to 240/250 °C	10651	10654	10657
0.53 mm	0.25 µm	40 to 250/260 °C	10622	10625	10628
	0.50 µm	40 to 250/260 °C	10637	10640	10643
	1.00 µm	40 to 240/250 °C	10652	10655	10658
	1.50 µm	40 to 230/240 °C	10666	10669	10672
	2.00 µm	40 to 220/230 °C	10667	10670	

ID	df	temp. limits	10-Meter cat.#	20-Meter cat.#
0.15 mm	0.15 µm	40 to 250/260 °C	43830	43831
0.18 mm	0.18 µm	40 to 250 °C		40602

*Maximum temperatures listed are for shorter length columns. Longer columns may have a different maximum temperature.

FAMEWAX Columns (USP G16) (fused silica)
polar phase; Crossbond polyethylene glycol

ID	df	temp. limits	30-Meter cat.#
0.25 mm	0.25 µm	20 to 240/250 °C	12497
0.32 mm	0.25 µm	20 to 240/250 °C	12498
0.53 mm	0.50 µm	20 to 250 °C	12499

Rt-2560 Column (fused silica)
highly polar phase; biscyanopropyl polysiloxane—not bonded

ID	df	temp. limits	100 m* cat.#
0.25 mm	0.20 µm	20 to 250 °C	13198

*Nominal length = 100 m. The actual length is 110 m, which is equivalent to the length of the previous Rt-2560 column (cat.# 13199).

Rtx-2330 Columns (fused silica)
highly polar phase; biscyanopropyl cyanopropylphenyl polysiloxane

ID	df	temp. limits*	30-Meter cat.#	60-Meter cat.#	105-Meter cat.#
0.25 mm	0.10 µm	0 to 260/275 °C	10708	10711	10714
	0.20 µm	0 to 260/275 °C	10723	10726	10729
0.32 mm	0.20 µm	0 to 260/275 °C	10724	10727	10730
0.53 mm	0.20 µm	0 to 260/275 °C	10725		

ID	df	temp. limits	10-Meter cat.#	20-Meter cat.#	40-Meter cat.#
0.18 mm	0.10 µm	0 to 260 °C	40701	40702	40703

*Maximum temperatures listed are for shorter length columns. Longer columns may have a different maximum temperature.

2.0 mL, 11 mm Crimp Vial Convenience Kits (Vials, Caps, & Septa)

Vials packaged in a clear-lid tray. Caps with septa packaged in a plastic bag.

Description	100-pk.	1,000-pk.
Clear 2.0 mL Vial, Deactivated, Silver Seal, PTFE/Natural Rubber Septa	24671	24672
Amber 2.0 mL Vial, Deactivated, Silver Seal, PTFE/Natural Rubber Septa	24673	24674
Clear 2.0 mL Vial, Untreated, Silver Seal, PTFE/Natural Rubber Septa	21196	21197
Amber 2.0 mL Vial, Untreated, Silver Seal, PTFE/Natural Rubber Septa	21198	21199
Clear 2.0 mL Vial, Untreated, Silver Seal, PTFE/Silicone Septa	24646	24647
Amber 2.0 mL Vial, Untreated, Silver Seal, PTFE/Silicone Septa	24648	24649

Inserts
for 2.0 mL, 11 mm Crimp-Top & 2.0 mL, 9 mm Short-Cap, Screw-Thread Vials

Description	Volume	Material	100-pk.	1,000-pk.	
Big Mouth Insert w/Bottom Spring	50 µL	Glass	24513	21782	
Big Mouth Insert w/Bottom Spring	250 µL	Glass	21776	21777	
Big Mouth Insert w/Glass Flange (Step Design)*	250 µL	Glass	24516	21779	
Insert, Flat Bottom	350 µL	Glass	21780	24517	
Insert, Flat Bottom w/ID Ring	350 µL	Glass	24692	24693	
Big Mouth Insert w/Bottom Spring	250 µL	Polypropylene	24518	—	—
Big Mouth Insert w/Bottom Spring & Graduated Markings	250 µL	Polypropylene	24518A	—	—
Big Mouth Insert, Top Flange	250 µL	Polypropylene	24519	—	—
Big Mouth Insert, No Spring	250 µL	Polypropylene	24520	—	—

*Big Mouth insert w/glass flange (step design) not to be used with 9 mm screw-thread vials.

Marine Oil FAME Mix (20 components)

Chain, Compound (CAS#), % by Weight
C14:0 Methyl myristate (124-10-7), 6%
C14:1 Methyl myristoleate (56219-06-8), 1%
C16:0 Methyl palmitate (112-39-0), 16%
C16:1 Methyl palmitoleate (1120-25-8), 5%
C18:0 Methyl stearate (112-61-8), 8%
C18:1 Methyl oleate (112-62-9), 13%
C18:1 Methyl vaccenate (1937-63-9), 4%
C18:2 Methyl linoleate (112-63-0), 2%
C18:3 Methyl linolenate (301-00-8), 2%
C20:0 Methyl arachidate (1120-28-1), 1%
C20:1 Methyl 11-eicosenoate (2390-09-2), 9%
C20:2 Methyl 11,14-eicosadienoate (2463-02-7), 1%
C20:4 Methyl arachidonate (2566-89-4), 3%
C20:3 Methyl 11,14,17-eicosatrienoate (55682-88-7), 1%
C20:5 Methyl eicosapentaenoate (2734-47-6), 10%
C22:0 Methyl behenate (929-77-1), 1%
C22:1 Methyl erucate (1120-34-9), 3%
C22:6 Methyl docosahexaenoate (301-01-9), 12%
C24:0 Methyl lignocerate (2442-49-1), 1%
C24:1 Methyl nervonate (2733-88-2), 1%

cat.# 35066 (100 mg)

Quantity discounts not available.
No data pack available.

Food Industry FAME Mix (37 components)

Chain, Compound (CAS#), % by Weight
C4:0 Methyl butyrate (623-42-7), 4%
C6:0 Methyl caproate (106-70-7), 4%
C8:0 Methyl caprylate (111-11-5), 4%
C10:0 Methyl decanoate (110-42-9), 4%
C11:0 Methyl undecanoate (1731-86-8), 2%
C12:0 Methyl dodecanoate (111-82-0), 4%
C13:0 Methyl tridecanoate (1731-88-0), 2%
C14:0 Methyl myristate (124-10-7), 4%
C14:1 (*cis*-9) Methyl myristoleate (56219-06-8), 2%
C15:0 Methyl pentadecanoate (7132-64-1), 2%
C15:1 (*cis*-10) Methyl pentadecenoate (90176-52-6), 2%
C16:0 Methyl palmitate (112-39-0), 6%
C16:1 (*cis*-9) Methyl palmitoleate (1120-25-8), 2%
C17:0 Methyl heptadecanoate (1731-92-6), 2%
C17:1 (*cis*-10) Methyl heptadecenoate (75190-82-8), 2%
C18:0 Methyl stearate (112-61-8), 4%
C18:1 (*trans*-9) Methyl octadecenoate (1937-62-8), 2%
C18:1 (*cis*-9) Methyl oleate (112-62-9), 4%
C18:2 (all-*trans*-9,12) Methyl linolelaidate (2566-97-4), 2%
C18:2 (all-*cis*-9,12) Methyl linoleate (112-63-0), 2%
C18:3 (all-*cis*-6,9,12) Methyl linolenate (16326-32-2), 2%
C18:3 (all-*cis*-9,12,15) Methyl linolenate (301-00-8), 2%
C20:0 Methyl arachidate (1120-28-1), 4%
C20:1 (*cis*-11) Methyl eicosenoate (2390-09-2), 2%
C20:2 (all-*cis*-11,14,) Methyl eicosadienoate (2463-02-7), 2%
C20:3 (all-*cis*-8,11,14) Methyl eicosatrienoate (21061-10-9), 2%
C20:3 (all-*cis*-11,14,17) Methyl eicosatrienoate (55682-88-7), 2%
C20:4 (all-*cis*-5,8,11,14) Methyl arachidonate (2566-89-4), 2%
C20:5 (all-*cis*-5,8,11,14,17) Methyl eicosapentaenoate (2734-47-6), 2%
C21:0 Methyl heneicosanoate (6064-90-0), 2%
C22:0 Methyl behenate (929-77-1), 4%
C22:1 (*cis*-13) Methyl erucate (1120-34-9), 2%
C22:2 (all-*cis*-13,16) Methyl docosadienoate (61012-47-3), 2%
C22:6 (all-*cis*-4,7,10,13,16,19) Methyl docosahexaenoate (2566-90-7), 2%
C23:0 Methyl tricosanoate (2433-97-8), 2%
C24:0 Methyl lignocerate (2442-49-1), 4%
C24:1 (*cis*-15) Methyl nervonate (2733-88-2), 2%

30 mg/mL total in methylene chloride, 1 mL/ampul cat.# 35077 (ea.)

Quantity discounts not available.
No data pack available.

NLEA FAME Mix (28 components)

Chain, Compound (CAS#), % by Weight
C4:0 Methyl butyrate (632-42-7), 1.5%
C6:0 Methyl hexanoate (106-70-7), 1.5%
C8:0 Methyl octanoate (111-11-5), 2%
C10:0 Methyl decanoate (1110-42-9), 2.5%
C11:0 Methyl undecanoate (1731-86-8), 2.5%
C12:0 Methyl laurate (111-82-0), 5%
C13:0 Methyl tridecanoate (1731-88-0), 2.5%
C14:0 Methyl myristate (124-10-7), 2.5%
C14:1 (*cis*-9) Methyl myristoleate (56219-06-8), 1.5%
C15:0 Methyl pentadecanoate (7132-64-1), 1.5%
C16:0 Methyl palmitate (112-39-0), 10%
C16:1 (*cis*-9) Methyl palmitoleate (1120-25-8), 5%
C17:0 Methyl heptadecanoate (1731-92-6), 2.5%
C18:0 Methyl stearate (112-61-8), 5%
C18:1 (*trans*-9) Methyl elaidate (1937-62-8), 2.5%
C18:1 (*cis*-9) Methyl oleate (112-62-9), 15%
C18:2 (all-*trans*-9,12) Methyl linolelaidate (2566-97-4), 2.5%
C18:2 (all-*cis*-9,12) Methyl linoleate (112-63-0), 10%
C18:3 (all-*cis*-9,12,15) Methyl linolenate (301-00-8), 5%
C20:0 Methyl arachidate (1120-28-1), 2.5%
C20:1 (*cis*-11) Methyl eicosenoate (2380-09-2), 1.5%
C20:5 (all-*cis*-5,8,11,14,17) Methyl eicosapentaenoate (2734-47-6), 2.5%
C22:0 Methyl behenate (929-77-1), 2.5%
C22:1 (*cis*-13) Methyl erucate (1120-34-9), 1.5%
C22:6 (all-*cis*-4,7,10,13,16,19) Methyl docosahexaenoate (28061-46-3), 2.5%
C23:0 Methyl tricosanoate (2433-97-8), 1.5%
C24:0 Methyl lgnocerate (2422-49-1), 2.5%
C24:1 (*cis*-15) Methyl nervonate (2733-88-2), 2.5%

30 mg/mL total in methylene chloride, 1 mL/ampul cat.# 35078 (ea.)

Quantity discounts not available.
No data pack available.

cis/*trans* **FAME Mix** (8 components)

Chain, Compound (CAS#), % by Weight
C18:1 *trans*-9 Methyl elaidate (2462-84-2), 10%
C18:2 *cis*-9,12 Methyl linoleate (112-63-0), 20%
C18:1 *cis*-9 Methyl oleate (112-62-9), 10%
C18:1 *cis*-6 Methyl petroselinate (2777-58-4), 8%
C18:1 *trans*-6 Methyl petroselaidate (14620-36-1), 8%
C18:0 Methyl stearate (112-61-8), 20%
C18:1 *trans*-11 Methyl transvaccenate (6198-58-9), 12%
C18:1 *cis*-11 Methyl vaccenate (1937-63-9), 12%

10 mg/mL total in methylene chloride, 1 mL/ampul cat.# 35079 (ea.)

Quantity discounts not available.
No data pack available.

Neat Fatty Acid Methyl Esters

Use these materials to prepare specific mixtures not commercially available. These products are of the highest purity available, typically 99% by GC-FID analysis. Each compound is packaged under a nitrogen blanket to ensure product stability. A certificate of analysis is provided with each ampul.

Chain	Description	CAS #	qty.	cat.#
C6:0	Methyl caproate	106-70-7	ea.	35037
C8:0	Methyl caprylate	111-11-5	ea.	35039
C10:0	Methyl caprate	110-42-9	ea.	35041
C11:0	Methyl undecanoate	1731-86-8	ea.	35042
C12:0	Methyl laurate	111-82-0	ea.	35043
C13:0	Methyl tridecanoate	1731-88-0	ea.	35044
C14:0	Methyl myristate	124-10-7	ea.	35045
C16:0	Methyl palmitate	112-39-0	ea.	35048
C16:1 Δ 9 *cis*	Methyl palmitoleate	1120-25-8	ea.	35049
C17:0	Methyl heptadecanoate	1731-92-6	ea.	35050
C18:0	Methyl stearate	112-61-8	ea.	35051
C18:1 Δ 9 *cis*	Methyl oleate	112-62-9	ea.	35052
C18:2 Δ 9,12 *cis*	Methyl linoleate	112-63-0	ea.	35053
C18:3 Δ 9,12,15 *cis*	Methyl linolenate	301-00-8	ea.	35054
C19:0	Methyl nonadecanoate	1731-94-8	ea.	35055
C20:0	Methyl arachidate	1120-28-1	ea.	35056
C20:1 Δ 11 *cis*	Methyl eicosenoate	2390-09-2	ea.	35057
C20:3 Δ 11,14,17 *cis*	Methyl eicosatrienoate	55682-88-7	ea.	35059
C21:0	Methyl heneicosanoate	6064-90-0	ea.	35061
C22:0	Methyl behenate	929-77-1	ea.	35062
C22:1 Δ 13 *cis*	Methyl erucate	1120-34-9	ea.	35063
C24:0	Methyl lignocerate	2442-49-1	ea.	35064

Quantity discounts not available.
No data pack available.

trans Fat Reference Standard (13 components)

- For accurate determination of *trans* fat content in foods and edible oils.
- Pair with an Rt-2560 GC column for reliable AOAC and AOCS method performance.
- Verified composition and stability.

Chain, Compound, % by Weight
C14:1T Methyl Myristelaidate, 6%
C15:1T Methyl 10-Transpentadecenoate, 6%
C16:1T Methyl Palmitelaidate, 6%
C17:1T Methyl 10-Transheptadecenoate, 6%
C18:1T Methyl Elaidate, 16%
C18:1T Methyl Petroselaidate, 4%
C18:1T Methyl Transvaccenate, 12%
C18:1T Methyl Ricinelaidate, 8%
C18:2TT Methyl Linoelaidate, 6%
C19:1T Methyl 7-Transnonadecenoate, 6%
C19:1T Methyl-10-Transnonadecenoate, 12%
C20:1T Methyl 11-Transeicosenoate, 6%
C22:1T Methyl Brassidate, 6%

Neat blend, 6.0 – 16.0 wt/wt%, 100 mg/ampul — cat.# 35629 (ea.)

Quantity discounts not available.
No data pack available.

trans Fat Standards

- For accurate determination of *trans* fat content in foods and edible oils.
- Pair with an Rt-2560 GC column for reliable AOAC and AOCS method performance.
- Verified composition and stability.

Boron Trifluoride

Boron trifluoride is very sensitive to moisture and should not be stored after opening. This is a single-use container.

Boron trifluoride (7637-07-2)

14% in methanol, 5 mL/bottle — cat.# 35626 (ea.)

Quantity discounts not available.
No data pack available.

Tritridecanoin Glyceride

Tritridecanoin glyceride (26536-12-9)

Neat, 100 mg/vial — cat.# 35627 (ea.)

Quantity discounts not available.
No data pack available.

Triundecanoin

Triundecanoin (13552-80-2)

Neat, 100 mg/ampul — cat.# 35628 (ea.)

Quantity discounts not available.
No data pack available.

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Questions? Contact us or your local Restek representative (www.restek.com/contact-us).

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