Incorporating Ultrashort-Chain PFAS into Comprehensive PFAS Analysis in Liquid Milks

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Key Highlights

- Simple, streamlined sample preparation protocol minimizes contamination and maximizes recovery.
- Inert column hardware packed with a unique polar-embedded stationary phase and established method conditions provide accurate, precise results for the simultaneous analysis of ultrashort-chain, short-chain, long-chain, and alternative PFAS.
- Proven suitable for comprehensive assessment of PFAS contamination across a diverse range of liquid milk samples.

Related Products

- *Ultra IBD Inert, 3 µm, 100 x 2.1 mm HPLC Column*
- *Ultra IBD, 3 µm, 150 x 2.1 mm HPLC Column*
- *PFAS 28 Calibration Standard, 1 µg/mL, Methanol (1 mM KOH), 1 mL/ampul*
- *Empty Centrifuge Tubes, 50 mL, Polypropylene w/Cap, 50-pk.*

Abstract

Incorporating ultrashort-chain PFAS into methods that also include short-chain, long-chain, and alternative PFAS is essential for gaining a comprehensive assessment of PFAS contamination. The sample preparation and LC-MS/MS workflow established here provides an effective approach for quantitative monitoring of a diverse panel of PFAS, including ultrashort-chain analytes, in a wide range of milk matrices. The method was assessed based on linearity, accuracy, and precision parameters and then applied to real-world samples of various dairy milks, plant-based milks, and infant formula.

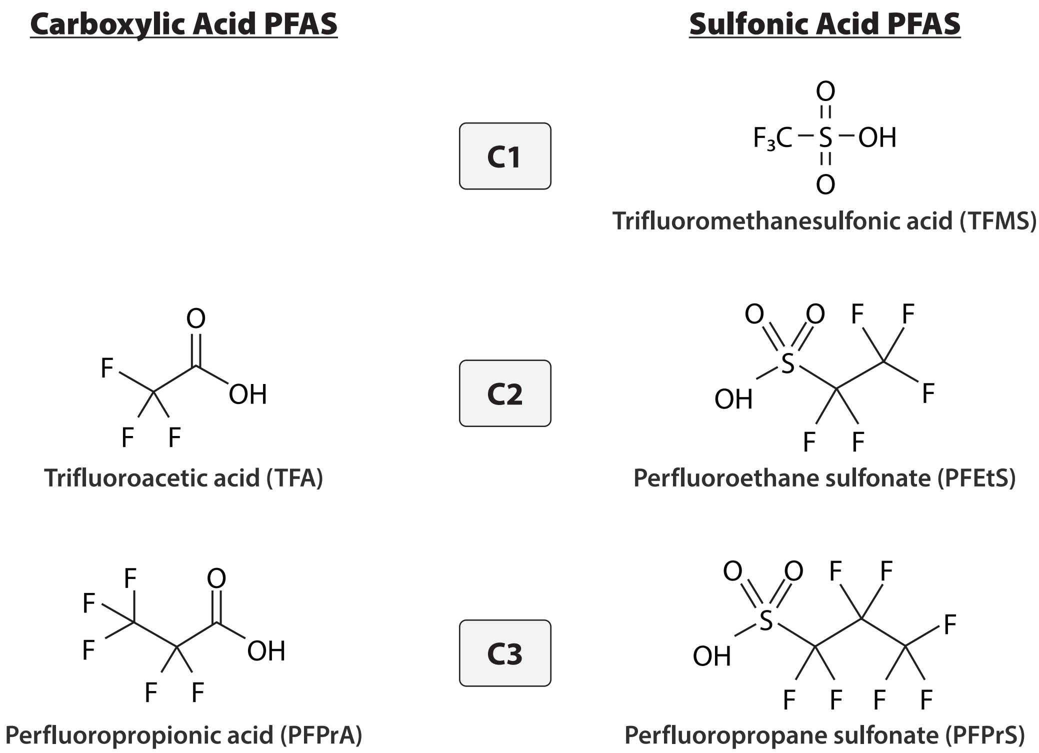
Introduction

Ultrashort-chain (USC) per- and polyfluoroalkyl substances (PFAS) are highly polar compounds with carbon chains shorter than C4 (Figure 1), and they are ubiquitous in aquatic environments. Their widespread occurrence has raised growing concerns about potential contamination in food products, particularly in ready-to-feed liquid milk products, which are widely consumed by infants and children. While effective methods exist for analyzing longer-chain PFAS in milk samples [1], to fully assess PFAS contamination, it is critical to include ultrashort-chain compounds.

Analyzing PFAS in milk poses unique challenges due to the complexity of the matrix, which contains proteins, fats, and other components that can interfere with detection. Ultrashort-chain PFAS and other shorter-chain compounds are particularly difficult to analyze as traditional multistep sample preparation methods can either contribute background PFAS contamination or lead to low recovery of the target analytes. In this study, a sample preparation procedure involving protein precipitation, extract dry-down, and reconstitution was developed and optimized for effective extraction and quantification of all analytes. In addition to sample preparation challenges, the high polarity of ultrashort-chain PFAS poses a significant difficulty for standard chromatographic practices in PFAS analysis, primarily due to insufficient chromatographic retention. The method developed here uses an inert-coated, polar-embedded, reversed-phase LC column to improve retention and sensitivity.

The combined sample preparation procedure and chromatographic method created a simple, reliable workflow for the simultaneous analysis of C1 to C14 perfluoroalkyl carboxylic and sulfonic acids, along with other PFAS classes, in various liquid milk matrices. Method verification was conducted using three different milk types (dairy milk, plant-based milk, and infant formula) to establish the workflow's suitability for detecting 41 PFAS. In addition, the method was tested across a wide range of real-world milk samples, demonstrating its effectiveness in comprehensive profiling of PFAS contamination across diverse milk matrices.

Figure 1: Structures of Ultrashort-Chain PFAS (C1 to C3)



Experimental

Evaluation of Background Contamination of Ultrashort-Chain PFAS

Given the widespread presence of ultrashort-chain PFAS in aquatic systems, ensuring the cleanliness of laboratory reagents and materials is crucial for accurate analysis. In particular, background contamination of TFA is a major concern as it can be present in solvents, reagents, and commonly used laboratory materials. Through extensive testing, the cleanest sources of water, acetonitrile, and methanol were identified for this study. Notably, significant variations in TFA detection signals were observed with different water sources used for the aqueous mobile phase, leading to the selection of ultrapure deionized water to ensure optimal sensitivity. Likewise, various pipette tips, HPLC vials, and centrifuge tubes used for standard and sample preparation were evaluated for contamination, allowing selection of the cleanest materials to maintain the integrity of our results.

Calibration standard solutions (500 µL) were prepared in polypropylene HPLC vials using a 1:1mixture of reverse osmosis water and acetonitrile with concentrations ranging from 4 to 2500ng/L. Eighteen mass-labeled PFAS were used as quantitative internal standards (QIS)(Table I). A 2.5 µL aliquot of QIS working solution, containing 10 ng/mL of each isotope, was added to each standard solution. The milk samples (0.5 g) were weighed into 15 mL polypropylene centrifuge tubes, spiked with 2.5 µL of 10 ng/mL QIS working solution, thoroughly mixed, and extracted with 1.5 mL of acetonitrile by vortexing for 2 minutes. The mixture was then centrifuged at 4000 rpm, and then the supernatant was transferred to a new 15 mL tube and dried under a gentle nitrogen stream in a 50 °C water bath. The dried residue was reconstituted with 0.5 mL of a 1:1 water:acetonitrile diluent, vortexed for 2 minutes, and centrifuged again at 4000 rpm. The final supernatant was transferred to polypropylene HPLC vials for LC-MS/MS analysis.

Evaluation of Method Accuracy and Precision

To demonstrate that the developed workflow can be applied to various milk matrices, three types of ready-to-feed milk samples—dairy whole milk, almond milk, and infant formula—were used to evaluate method accuracy and precision. Almond milk was selected to represent the plant-based milk due to its widespread consumption. These milk samples were fortified with native analytes at concentrations of 0.010, 0.025, 0.050, 0.10, and 0.25 µg/kg along with isotopically labeled ^{13}C-TFA, which served as a surrogate for TFA recovery determination. These concentrations correspond to 10, 25, 50, 100, and 250 ng/L in the final sample solution following the sample preparation procedure described above. Incurred PFAS were detected in all three milk samples, and their concentrations were subtracted from the calculated concentrations of fortified samples to determine the recovery. Table I illustrates the pairing of QIS with various analytes for quantification. Due to differential matrix effects, some analytes in almond milk required alternative QIS for more accurate quantification.

Analytical Conditions

In this approach for incorporating ultrashort-chain PFAS and related compounds into a single method, analysis was performed by LC-MS/MS using a Waters ACQUITY UPLC I-Class liquid chromatograph and Xevo TQ-S triple quadrupole mass spectrometer under the conditions shown below. Ion transitions, MS settings, and the internal standard used to quantify each PFAS are given in Table I. An Ultra IBD column (150 × 2.1 mm, 3.0 µm) was employed as the delay column to more effectively remove background contamination originating from the instrument and mobile phases. Although a standard C18 PFAS delay column is typically adequate, it did not provide acceptable separation between background contaminants and target analytes when coupled with the Ultra IBD Inert analytical column.

Columns:
- Analytical column: Ultra IBD Inert, 3.0 µm, 100 x 2.1 mm (cat.# 9175312-T)
- Delay column: Ultra IBD, 3.0 µm, 150 x 2.1 mm (cat.# 9175362)

Injection volume: 5 µL
Mobile phase A: 5 mM ammonium formate, 0.1% formic acid in water
Mobile phase B: Acetonitrile
Flow rate: 0.4 mL/min
Temperature: 40 °C
Gradient:

Time (min)	%B
0.00	45
7.00	95
11.00	95
11.01	45
13.00	45

Ion mode: Negative ESI
Mode: Scheduled MRM

Table I: MS/MS Parameters and Internal Standards

Compounds	Retention Time (min)	Precursor Ion	Product Ions[a]	Cone (V)	Collision (V)	QIS
Target Analytes						
Perfluoroalkyl Carboxylic Acids						
Trifluoroacetic acid (TFA)	1.60	113.03 [M-H]-	69.01	10	10	$^{13}C_2$-TFA
Perfluoropropanoic acid (PFPrA)	2.21	162.97 [M-H]-	119.02	10	8	$^{13}C_3$-PFPrA
Perfluorobutanoic acid (PFBA)	2.86	213.03 [M-H]-	168.98	14	8	$^{13}C_4$-PFBA
Perfluoropentanoic acid (PFPeA)	3.64	262.97 [M-H]-	218.97	2	6	$^{13}C_5$-PFPeA
Perfluorohexanoic acid (PFHxA)	4.41	313.10 [M-H]-	268.97/118.99	2	8/20	$^{13}C_5$-PFHxA
Perfluoroheptanoic acid (PFHpA)	5.15	363.16 [M-H]-	319.09/169.06	8	10/18	$^{13}C_4$-PFHpA
Perfluorooctanoic acid (PFOA)	5.84	413.10 [M-H]-	368.96/168.90	2	10/16	$^{13}C_8$-PFOA
Perfluorononanoic acid (PFNA)	6.48	463.10 [M-H]-	419.01/219.02	4	10/16	$^{13}C_9$PFNA
Perfluorodecanoic acid (PFDA)	7.08	513.17 [M-H]-	469.16/219.06	4	12/16	$^{13}C_6$-PFDA
Perfluoroundecanoic acid (PFUnA)	7.65	563.23 [M-H]-	519.24/269.07	6	12/18	$^{13}C_7$-PFUnA
Perfluorododecanoic acid (PFDoA)	8.26	613.23 [M-H]-	569.19/169.06	8	12/26	$^{13}C_2$-PFDoA
Perfluorotridecanoic acid (PFTrDA)	8.94	663.23 [M-H]-	619.21/169.06	8	14/28	$^{13}C_2$-PFTeDA
Perfluorotetradecanoic acid (PFTeDA)	9.75	712.67 [M-H]-	668.69/168.94	10	12/26	$^{13}C_2$-PFTeDA
Perfluoroalkyl Sulfonic Acids						
Trifluoromethanesulfonic acid (TFMS)	1.98	148.97 [M-H]-	79.93/98.92	62	18/18	$^{13}C_3$-PFBS
Perfluoroethanesulfonic acid (PFEtS)	2.62	198.90 [M-H]-	79.92/98.91	38	22/22	$^{13}C_4$-PFBA
Perfluoropropanesulfonic acid (PFPrS)	3.30	248.97 [M-H]-	79.92/98.91	2	24/24	$^{13}C_5$-PFPeA
Perfluorobutanesulfonic acid (PFBS)	3.96	298.97 [M-H]-	79.97/98.89	2	26/26	$^{13}C_3$-PFBS
Perfluoropentanesulfonic acid (PFPeS)	4.59	349.10 [M-H]-	79.98/98.98	6	32/30	$^{13}C_5$-PFHxA / $^{13}C_8$-PFOSb
Perfluorohexanesulfonic acid (PFHxS)	5.17	398.90 [M-H]-	79.97/98.89	56	32/34	$^{13}C_3$-PFHxS
Perfluoroheptanesulfonic acid (PFHpS)	5.70	449.17 [M-H]-	79.98/98.97	4	42/38	$^{13}C_8$-PFOA
Perfluorooctanesulfonic acid (PFOS)	6.19	499.03 [M-H]-	79.92/98.90	8	40/40	$^{13}C_8$-PFOS
Perfluorononanesulfonic acid (PFNS)	6.65	549.10 [M-H]-	79.92/98.83	12	42/40	$^{13}C_8$-PFOS
Perfluorodecanesulfonic acid (PFDS)	7.06	599.17 [M-H]-	79.98/98.83	8	44/46	$^{13}C_8$-PFOS / $^{13}C_2$-PFDoAb
Perfluoroundecanesulfonic acid (PFUdS)	7.43	648.73 [M-H]-	79.94/98.94	38	50/44	$^{13}C_8$-PFOS / $^{13}C_2$-PFDoAb
Perfluorododecanesulfonic acid (PFDoS)	7.77	698.77 [M-H]-	79.95/98.94	10	60/44	$^{13}C_8$-PFOS / $^{13}C_2$-PFDoAb
Perfluorotridecanesulfonic acid (PFTrDS)	8.08	748.73 [M-H]-	79.94/98.94	8	76/52	$^{13}C_8$-PFOS / $^{13}C_2$-PFDoAb
Fluorotelomer Sulfonic Acids						
1H,1H,2H,2H-Perfluorohexane sulfonic acid (4:2 FTS)	3.92	327.10 [M-H]-	307.08/80.83	50	18/24	$^{13}C_4$-PFBA / $^{13}C_5$-PFHxAb
1H,1H,2H,2H-Perfluorooctane sulfonic acid (6:2 FTS)	5.57	427.17 [M-H]-	407.18/80.71	2	22/32	$^{13}C_8$-PFOA
1H,1H,2H,2H-Perfluorodecane sulfonic acid (8:2 FTS)	7.07	527.17 [M-H]-	507.16/80.83	66	26/32	$^{13}C_3$-PFHxS / d5-NEtFOSAAb
Perfluoroalkyl Sulfonamides						
Perfluorooctanesulfonamide (FOSA)	4.01	498.17 [M-H]-	77.97/477.76	8	28/26	$^{13}C_8$-FOSA

Table I *(Continued)*

Compounds	Retention Time (min)	Precursor Ion	Product Ions[a]	Cone (V)	Collision (V)	QIS
Perfluoroalkyl Sulfonamidoacetic Acids						
N-methyl perfluorooctanesulfonamidoacetic acid (NMeFOSAA)	6.40	570.20 [M-H]-	419.17/483.16	46	20/14	d3-NMeFOSAA
N-ethyl perfluorooctanesulfonamidoacetic acid (NEtFOSAA)	6.52	584.20 [M-H]-	419.18/483.11	6	20/16	d5-NEtFOSAA
Per- and Polyfluoroether Carboxylic Acids						
Perfluoro-3-methoxypropanoic acid (PFMPA)	3.05	228.93 [M-H]-	84.97/198.94	10	10/14	$^{13}C_4$-PFBA
Perfluoro-4-methoxybutanoic acid (PFMBA)	3.76	278.87 [M-H]-	84.96/234.93	8	10/6	$^{13}C_5$-PFPeA
Hexafluoropropylene oxide dimer acid (HFPO-DA)	4.37	285.03 [M-COOH]-	169.02/185.02	2	6/16	$^{13}C_5$-PFHxA
4,8-Dioxa-3H-perfluorononanoic acid (ADONA)	4.71	376.90 [M-H]-	250.93/84.97	22	12/26	$^{13}C_4$-PFHpA
Per- and Polyfluoroether Sulfonic Acids						
Perfluoro(2-ethoxyethane)sulfonic acid (PFEESA)	4.09	314.83 [M-H]-	134.94/83.01	4	22/16	$^{13}C_3$-PFBS
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid (9Cl-PF3ONS)	6.20	530.78 [M-H]-	350.85/82.96	12	26/24	$^{13}C_8$-PFOA
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3OUdS)	6.92	630.78 [M-H]-	450.80/82.95	8	26/32	$^{13}C_8$-PFOS
Capstone Surfactants						
Capstone A	0.95	527.08 [M-H]-	507.02/181.06	2	10/12	$^{13}C_2$-TFA / $^{13}C_3$-PFPrAb
Capstone B	1.90	569.07 [M-H]-	549.01/445.96	32	12/16	$^{13}C_3$-PFPrA
Quantification Internal Standards						
$^{13}C_2$-TFA	2.69	114.90 [M-H]-	69.95	14	8	
$^{13}C_3$-PFPrA	2.69	165.97 [M-H]-	120.96	10	11	
$^{13}C_4$-PFBA	3.27	217.03 [M-H]-	171.98	2	8	
$^{13}C_5$-PFPeA	3.94	267.97 [M-H]-	222.99	2	6	
$^{13}C_5$-PFHxA	4.59	318.03 [M-H]-	272.93	2	7	
$^{13}C_4$-PFHpA	5.24	366.90 [M-H]-	321.93	2	10	
$^{13}C_8$-PFOA	5.86	420.97 [M-H]-	375.94	2	10	
$^{13}C_9$PFNA	5.86	471.97 [M-H]-	426.87	4	12	
$^{13}C_6$-PFDA	7.03	518.90 [M-H]-	473.87	4	13	
$^{13}C_7$-PFUnA	7.60	569.90 [M-H]-	524.87	2	12	
$^{13}C_2$-PFDoA	8.23	614.84 [M-H]-	569.87	2	12	
$^{13}C_2$-PFTeDA	9.83	714.78 [M-H]-	669.80	8	14	
$^{13}C_3$-PFBS	3.97	301.97 [M-H]-	79.97	2	28	
$^{13}C_3$-PFHxS	5.01	401.90 [M-H]-	79.97	2	36	
$^{13}C_8$-PFOS	5.96	506.84 [M-H]-	79.97	4	42	
$^{13}C_8$-FOSA	3.36	505.91 [M-H]-	77.95	4	32	
d3-NMeFOSAA	6.44	572.90 [M-H]-	418.91	50	18	
d5-NEtFOSAA	6.56	588.97 [M-H]-	418.86	48	20	

[a]Quantifier ion/qualifier ion

[b]Used for quantification in almond milk

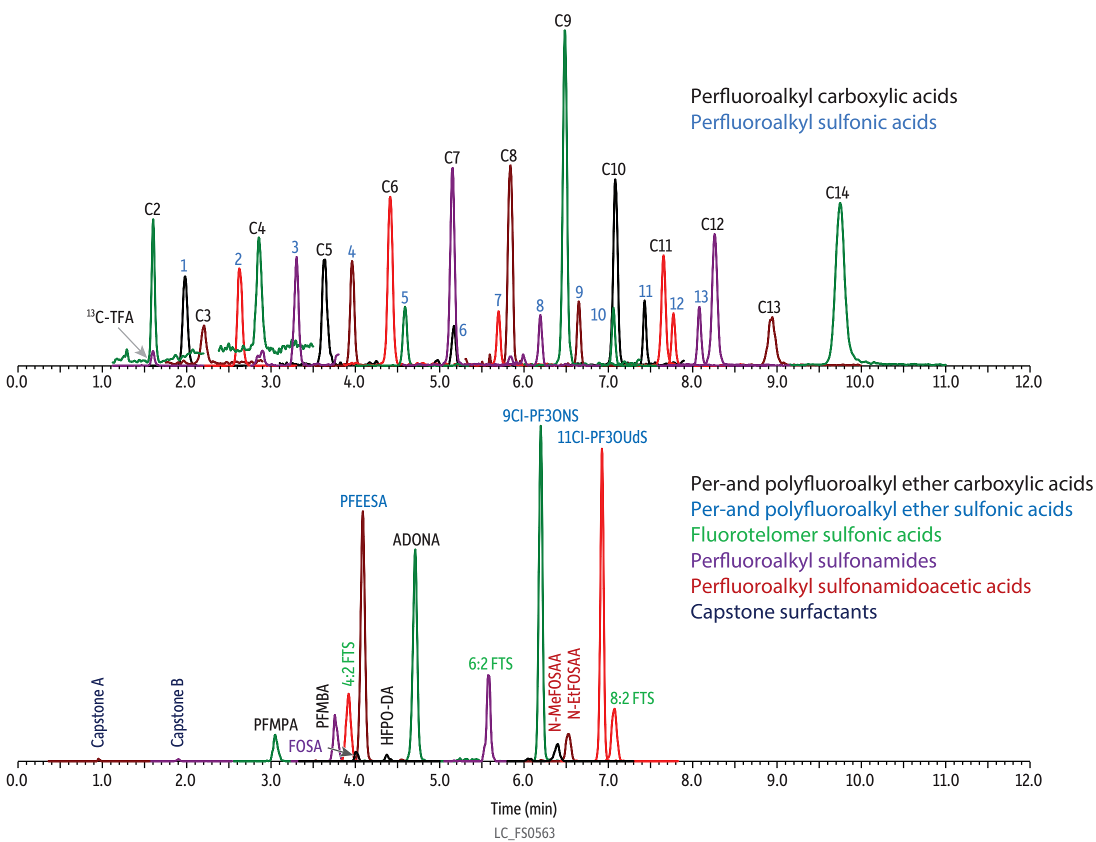
Results and Discussion

Chromatographic Performance

Analytical methods were previously developed for incorporating ultrashort-chain PFAS into comprehensive methods for testing PFAS in various water matrices [2] and human blood [3]. These methods utilized a polar-embedded alkyl Ultra IBD stationary phase to ensure adequate retention of highly polar ultrashort-chain PFAS. Additionally, it was demonstrated that an inert-coated Ultra IBD column could significantly enhance detection sensitivity for the majority of PFAS compounds [2] because it is made with hardware treated with an inert coating that prevents any unwanted analyte interactions with the stainless-steel surface of the column. The current study also applied a similar chromatographic methodology for PFAS analysis in milk samples. However, due to stronger matrix interference compared to water matrices, the injection volume was limited to 5 µL to maintain optimal chromatographic peak shapes for early-eluting compounds.

Figure 2 shows a typical chromatogram for the analysis of a fortified milk sample. In addition to the 28 PFAS compounds assessed under EURL guidance [4], this analysis was expanded to 41 analytes by incorporating ultrashort-chain PFAS, fluorotelomer sulfonic acids, and a broader range of alternative PFAS compounds. The EURL guidance notes that bile acids, such as tauroursodeoxycholic acid (TUDCA); taurochenodeoxycholic acid (TCDCA); and taurodeoxycholic acid (TDCA) can be present at high concentrations in milk samples and may interfere with PFOS quantification due to their shared mass transitions. Our tests confirmed that TUDCA, TCDCA, and TDCA all had distinct retention times from PFOS, ensuring they will not influence the accuracy of PFOS results (Figure 3). Furthermore, these bile acids displayed significantly lower detection sensitivity (~100-fold lower) than PFOS and were not detected in the final milk sample solutions analyzed in this study.

Figure 2: Analysis of a 0.1 µg/kg Fortified Whole Milk Sample



RESTEK

Figure 2 *(Continued)*

Peaks	t_R (min)	Precursor Ion	Quantification Ion	Confirmation Ion
1. Capstone A	0.95	527.08	507.02	181.06
2. Trifluoroacetic acid (TFA)	1.60	113.03	69.01	
3. 13C-Trifluoroacetic acid (13C-TFA)	1.60	114.03	69.03	
4. Capstone B	1.90	569.07	549.01	445.96
5. Trifluoromethanesulfonic acid (TFMS)	1.98	148.97	79.93	98.92
6. Perfluoropropanoic acid (PFPrA)	2.21	162.97	119.02	
7. Perfluoroethanesulfonic acid (PFEtS)	2.62	198.90	79.92	98.91
8. Perfluoro-3-methoxypropanoic acid (PFMPA)	3.05	228.93	84.97	198.94
9. Perfluoropropanesulfonic acid (PFPrS)	3.30	248.97	79.92	98.91
10. Perfluoropentanoic acid (PFPeA)	3.64	262.97	218.97	
11. Perfluoro-4-methoxybutanoic acid (PFMBA)	3.76	278.87	84.96	234.93
12. 1H,1H,2H,2H-Perfluorohexane sulfonic acid (4:2 FTS)	3.92	327.10	307.08	80.83
13. Perfluorobutanesulfonic acid (PFBS)	3.96	298.97	79.97	98.89
14. Perfluorooctanesulfonamide (FOSA)	4.01	498.17	77.97	477.76
15. Perfluoro(2-ethoxyethane)sulfonic acid (PFEESA)	4.09	314.83	134.94	83.01
16. Hexafluoropropylene oxide dimer acid (HFPO-DA)	4.37	285.03	169.02	185.02
17. Perfluorohexanoic acid (PFHxA)	4.41	313.10	268.97	118.99
18. Perfluoropentanesulfonic acid (PFPeS)	4.59	349.10	79.98	98.98
19. 4,8-Dioxa-3H-perfluorononanoic acid (ADONA)	4.71	376.90	250.93	84.97
20. Perfluoroheptanoic acid (PFHpA)	5.15	363.16	319.09	169.06
21. Perfluorohexanesulfonic acid (PFHxS)	5.17	398.90	79.97	98.89
22. 1H,1H,2H,2H-Perfluorooctane sulfonic acid (6:2 FTS)	5.57	427.17	407.18	80.71
23. Perfluoroheptanesulfonic acid (PFHpS)	5.70	449.17	79.98	98.97
24. Perfluorooctanoic acid (PFOA)	5.84	413.10	368.96	168.90
25. Perfluorooctanesulfonic acid (PFOS)	6.19	499.03	79.92	98.90
26. 9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid (9Cl-PF3ONS)	6.20	530.78	350.85	82.96
27. N-methyl perfluorooctanesulfonamidoacetic acid (NMeFOSAA)	6.40	570.20	419.17	483.16
28. Perfluorononanoic acid (PFNA)	6.48	463.10	419.01	219.02
29. N-ethyl perfluorooctanesulfonamidoacetic acid (NEtFOSAA)	6.52	584.20	419.18	483.11
30. Perfluorononanesulfonic acid (PFNS)	6.65	549.10	79.92	98.83
31. 11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3OUdS)	6.92	630.78	450.80	82.95
32. Perfluorodecanesulfonic acid (PFDS)	7.06	599.17	79.98	98.83
33. 1H,1H,2H,2H-Perfluorodecane sulfonic acid (8:2 FTS)	7.07	527.17	507.16	80.83
34. Perfluorodecanoic acid (PFDA)	7.08	513.17	469.16	219.06
35. Perfluoroundecanesulfonic acid (PFUdS)	7.43	648.73	79.94	98.94
36. Perfluoroundecanoic acid (PFUnA)	7.65	563.23	519.24	269.07
37. Perfluorododecanesulfonic acid (PFDoS)	7.77	698.77	79.95	98.94
38. Perfluorotridecanesulfonic acid (PFTrDS)	8.08	748.73	79.94	98.94
39. Perfluorododecanoic acid (PFDoA)	8.26	613.23	569.19	169.06
40. Perfluorotridecanoic acid (PFTrDA)	8.94	663.23	619.21	169.06
41. Perfluorotetradecanoic acid (PFTeDA)	9.75	712.67	668.69	168.94

Column Ultra IBD Inert (cat.# 9175312-T)
Dimensions: 100 mm x 2.1 mm ID
Particle Size: 3 µm
Pore Size: 100 Å
Temp.: 40 °C

Standard/Sample
PFAS 28 calibration standard (cat.# 30734)
Other standards were obtained externally.
Diluent: 50:50 water:acetonitrile
Conc.: Whole milk fortified at 0.1 µg/kg
Inj. Vol.: 5 µL

Mobile Phase
A: Water, 5mM ammonium formate, 0.1% formic acid
B: Acetonitrile

Time (min)	Flow (mL/min)	%A	%B
0.00	0.4	55	45
7.00	0.4	5	95
11.00	0.4	5	95
11.01	0.4	55	45
13.00	0.4	55	45

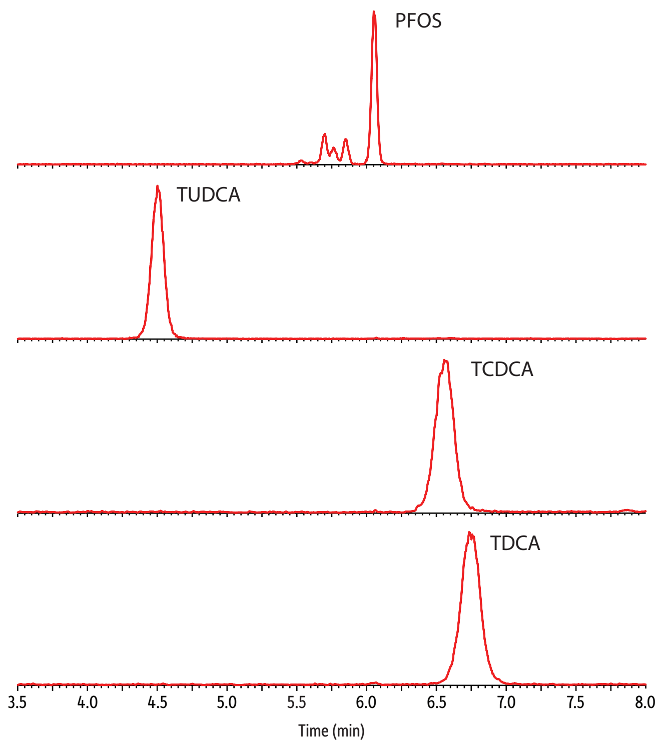
Max Pressure: 540 bar
Detector Waters Xevo TQ-S
Ion Source: Waters Zspray ESI
Ion Mode: ESI-
Mode: MRM

Instrument Waters ACQUITY UPLC I-Class

Sample Preparation Milk samples (0.5 g) were weighed into 15 mL polypropylene centrifuge tubes, spiked with analytes at 0.1 µg/kg, thoroughly mixed, and extracted with 1.5 mL of acetonitrile by vortexing for 2 minutes. The mixture was then centrifuged at 4000 rpm, and the supernatant was transferred to a new 15 mL tube and dried under a gentle nitrogen stream in a 50°C water bath. The dried residue was reconstituted with 0.5 mL of a 1:1 water:acetonitrile diluent, vortexed for 2 minutes, and centrifuged again at 4000 rpm. The final supernatant was transferred to polypropylene HPLC vials for LC-MS/MS analysis.

Notes The confirmation ion peaks were not shown in the chromatogram.
An Ultra IBD column (150 x 2.1 mm, 3.0 µm; cat # 9175362) was used as the delay column.
For the chromatograms of perfluoroalkyl carboxylic and sulfonic acids, the peak numbers correspond to the carbon chain lengths of the PFAS compounds.

Figure 3: Full Chromatographic Separation of PFOS and Potentially Interfering Bile Acids



LC_FS0565

Peaks	t_R (min)	Conc. (ng/mL)	Precursor Ion	Confirmation Ion
1. Tauroursodeoxycholic acid (TUDCA)	4.50	100	499.03	79.92
2. Perfluorooctanesulfonic acid (PFOS)	6.05	0.5	499.03	79.92
3. Taurochenodeoxycholic acid (TCDCA)	6.55	100	499.03	79.92
4. Taurodeoxycholic acid (TDCA)	6.74	100	499.03	79.92

Column	Ultra IBD Inert (cat.# 9175312-T)
Dimensions:	100 mm x 2.1 mm ID
Particle Size:	3 µm
Pore Size:	100 Å
Temp.:	40 °C
Standard/Sample	Individual standards were obtained externally.
Diluent:	50:50 water:acetonitrile
Inj. Vol.:	5 µL
Mobile Phase	
A:	Water, 5 mM ammonium formate, 0.1% formic acid
B:	Acetonitrile

Time (min)	Flow (mL/min)	%A	%B
0.00	0.4	55	45
7.00	0.4	5	95
11.00	0.4	5	95
11.01	0.4	55	45
13.00	0.4	55	45

Max Pressure:	540 bar
Detector	Waters Xevo TQ-S
Ion Source:	Waters Zspray ESI
Ion Mode:	ESI-
Mode:	MRM
Instrument	Waters ACQUITY UPLC I-Class
Sample Preparation	Individual standards were prepared in 50:50 water:acetonitrile solution in polypropylene HPLC vials.
Notes	An Ultra IBD column (150 x 2.1 mm, 3.0 µm; cat. # 9175362) was used as the delay column.

Linearity

Employing quadratic regression (1/x weighted), all analytes exhibited acceptable linearities with r^2 >0.995 and deviations <30%. The calibration ranges were 20–2500 ng/L for TFA; 20–1000 ng/L for HFPO-DA, capstone A, and capstone B; and 4–1000 ng/L for the remaining analytes.

Accuracy and Precision

Three batches of analyses were conducted on different days, totaling nine replicates at each fortified level. The average recovery and relative standard deviation (RSD) for each PFAS in each matrix are presented in Table III. All analytes exhibited recovery values within the range of 78.3–119% in whole milk, 81.6–129% in almond milk, and 80.5–118% in infant formula. Satisfactory method precision was demonstrated by the %RSD values being ≤15%. Due to higher matrix suppression or poor detection signals, the recovery of ^{13}C-TFA, PFPrA, FOSA, HFPO-DA, capstone A, capstone B, and PFMPA could not be determined in some or all of the 0.01 µg/kg fortified samples. Capstone A could not be identified and measured in almond milk due to specific matrix suppression.

Table II: Accuracy and Precision Analysis of PFAS in Fortified Milk Samples

Whole Milk

	Average Recovery (RSD, %), n=9				
	Fortified Concentration (µg/kg)				
Analytes	**0.010**	**0.025**	**0.050**	**0.10**	**0.25**
^{13}C-TFA	–	104 (9.40)	108 (6.19)	111 (7.65)	114 (6.02)
PFPrA	110 (9.22)	108 (9.29)	114 (5.59)	112 (7.55)	119 (4.73)
PFBA	115 (3.43)	104 (6.80)	111 (8.73)	108 (4.26)	112 (3.60)
PFPeA	106 (8.48)	91.3 (8.68)	92.0 (10.0)	97.5 (12.4)	102 (6.73)
PFHxA	108 (4.27)	87.9 (7.77)	92.6 (9.97)	90.9 (10.8)	105 (5.71)
PFHpA	113 (4.65)	93.7 (6.82)	92.1 (8.58)	90.3 (6.51)	103 (9.38)
PFOA	112 (9.69)	91.6 (12.9)	83.3 (11.4)	86.9 (4.64)	103 (10.5)
PFNA	114 (7.32)	102 (7.47)	101 (6.33)	105 (5.50)	110 (4.46)
PFDA	110 (10.7)	86.4 (8.71)	88.8 (8.37)	95.3 (10.8)	103 (9.83)
PFUnA	109 (8.75)	87.3 (11.8)	95.1 (9.90)	95.0 (10.7)	96.4 (13.9)
PFDoA	113 (7.22)	81.7 (8.30)	88.5 (9.97)	93.6 (6.06)	97.5 (15.0)
PFTrDA	113 (8.61)	85.4 (4.62)	86.7 (4.92)	95.2 (9.83)	95.4 (3.12)
PFTeDA	105 (13.5)	78.9 (7.25)	85.1 (12.2)	96.1 (8.25)	98.3 (15.1)
TFMS	112 (7.81)	107 (10.4)	112 (5.96)	82.9 (5.82)	84.6 (7.92)
PFEtS	104 (9.39)	103 (7.51)	105 (7.90)	114 (5.96)	116 (5.55)
PFPrS	95.7 (5.72)	87.6 (7.53)	94.5 (5.08)	91.3 (12.9)	99.7 (7.59)
PFBS	104 (12.7)	95.8 (13.0)	99.1 (9.98)	100 (10.3)	109 (8.59)
PFPeS	102 (9.04)	93.5 (12.4)	90.2 (11.5)	93.8 (14.0)	107 (13.5)
PFHxS	104 (8.83)	90.6 (12.4)	85.2 (8.26)	88.2 (8.90)	108 (10.4)
PFHpS	85.9 (4.54)	85.0 (4.97)	84.6 (8.85)	83.5 (3.94)	97.4 (10.0)
PFOS	109 (6.76)	102 (10.3)	102 (7.83)	93.0 (13.7)	102 (10.5)
PFNS	104 (10.8)	88.4 (11.0)	96.8 (14.1)	86.9 (5.59)	103 (10.4)
PFDS	98.5 (12.7)	91.7 (12.0)	97.3 (13.5)	95.8 (14.3)	106 (7.60)
PFUdS	86.1 (5.93)	93.1 (7.89)	105 (10.9)	91.0 (8.73)	108 (6.82)
PFDoS	116 (3.54)	78.3 (8.12)	101 (7.02)	86.5 (9.40)	102 (9.72)
PFTrDS	95.7 (14.4)	81.0 (2.20)	93.3 (6.78)	91.7 (13.2)	106 (10.5)
4:2 FTS	103 (8.31)	102 (12.1)	102 (10.2)	113 (8.30)	116 (2.94)
6:2 FTS	108 (9.23)	115 (6.07)	96.4 (9.84)	87.9 (10.2)	109 (5.90)
8:2 FTS	92.5 (15.3)	94.2 (12.3)	90.5 (7.92)	83.1 (5.62)	95.0 (8.98)

Table II *(Continued)*

Whole Milk *(continued)*

	Average Recovery (RSD, %), n=9				
	Fortified Concentration (µg/kg)				
Analytes	**0.010**	**0.025**	**0.050**	**0.10**	**0.25**
FOSA	–	103 (8.53)	88.3 (12.9)	96.3 (13.2)	112 (6.15)
NMeFOSAA	107 (9.71)	86.6 (8.05)	86.1 (8.46)	92.4 (10.7)	98.9 (12.9)
NEtFOSAA	107 (7.37)	94.3 (8.12)	94.8 (10.6)	105 (7.31)	110 (5.73)
PFMPA	86.1 (9.47)	88.4 (8.49)	84.0 (9.50)	85.4 (5.55)	90.4 (7.52)
PFMBA	87.4 (10.3)	98.5 (11.8)	85.8 (8.29)	98.6 (8.80)	102 (5.72)
HFPO-DA	–	98.7 (13.5)	96.9 (9.14)	88.2 (15.1)	98.6 (14.0)
ADONA	113 (4.56)	87.7 (7.80)	85.9 (7.20)	84.5 (1.90)	91.5 (8.03)
PFEESA	94.1 (10.6)	91.2 (12.4)	98.4 (11.7)	104 (8.42)	110 (7.01)
9Cl-PF3ONS	93.2 (7.90)	80.5 (7.82)	83.7 (5.62)	88.6 (5.48)	97.2 (11.2)
11Cl-PF3OUdS	99.8 (8.00)	82.3 (6.39)	92.4 (9.85)	101 (13.3)	106 (8.15)
Capstone A	–	85.9 (11.8)	103 (9.31)	111 (5.74)	118 (6.80)
Capstone B	–	108 (8.60)	99.9 (15.0)	113 (4.46)	118 (2.83)

Almond Milk

	Average Recovery (RSD, %), n=9				
	Fortified Concentration (µg/kg)				
Analytes	**0.010**	**0.025**	**0.050**	**0.10**	**0.25**
^{13}C-TFA	–	127 (4.47)	129 (2.78)	125 (7.85)	110 (8.27)
PFPrA	–	120 (5.45)	115 (6.71)	114 (5.40)	119 (5.62)
PFBA	112 (7.95)	106 (8.08)	103 (8.48)	98.0 (6.45)	101 (14.2)
PFPeA	97.1 (7.51)	101 (10.8)	99.5 (10.8)	92.1 (8.40)	95.4 (7.09)
PFHxA	90.8 (12.2)	111 (10.1)	100 (7.90)	94.0 (6.60)	102 (9.41)
PFHpA	116 (5.79)	98.8 (6.45)	88.9 (5.97)	87.4 (6.15)	94.1 (6.10)
PFOA	109 (7.29)	113 (6.75)	102 (6.76)	109 (3.37)	114 (3.33)
PFNA	88.0 (8.26)	90.0 (7.59)	81.6 (6.43)	84.6 (4.29)	89.7 (7.17)
PFDA	106 (14.3)	95.0 (7.55)	84.7 (5.31)	92.6 (5.61)	94.2 (3.03)
PFUnA	105 (9.34)	93.4 (8.81)	99.1 (11.7)	108 (6.58)	106 (4.40)
PFDoA	115 (4.66)	114 (3.60)	114 (5.06)	119 (2.60)	119 (2.65)
PFTrDA	105 (8.08)	111 (4.47)	116 (6.70)	126 (3.29)	125 (3.64)
PFTeDA	106 (6.29)	112 (3.62)	118 (2.81)	128 (3.46)	128 (3.19)
TFMS	100 (9.22)	107 (7.45)	110 (4.41)	87.9 (5.54)	88.9 (8.59)
PFEtS	115 (6.22)	111 (7.45)	118 (3.40)	112 (6.29)	118 (3.93)
PFPrS	91.9 (8.44)	92.3 (5.94)	100 (8.15)	95.5 (4.92)	98.3 (7.83)
PFBS	112 (6.31)	92.1 (11.8)	98.9 (8.42)	90.1 (7.68)	101 (10.6)
PFPeS	99.7 (13.6)	111 (10.9)	103 (7.36)	100 (10.0)	106 (11.5)
PFHxS	100 (9.16)	95.9 (9.88)	101 (10.4)	111 (6.40)	108 (5.15)
PFHpS	86.9 (6.71)	96.0 (9.84)	84.5 (5.45)	92.1 (3.27)	99.5 (5.34)
PFOS	115 (4.37)	90.3 (10.9)	83.4 (5.20)	83.7 (7.66)	91.3 (8.34)
PFNS	89.6 (12.1)	92.3 (11.3)	82.8 (5.36)	95.0 (6.73)	93.0 (10.6)
PFDS	108 (12.8)	101 (11.6)	110 (5.53)	110 (9.70)	119 (3.14)
PFUdS	93.9 (11.4)	93.8 (9.55)	98.4 (7.86)	115 (1.83)	118 (3.13)
PFDoS	90.3 (7.00)	100 (9.86)	107 (6.95)	118 (2.42)	118 (2.26)

Table II *(Continued)*

Almond Milk *(continued)*

	Average Recovery (RSD, %), n=9				
	Fortified Concentration (µg/kg)				
Analytes	**0.010**	**0.025**	**0.050**	**0.10**	**0.25**
PFTrDS	95.9 (10.9)	94.0 (9.28)	99.6 (6.13)	114 (3.42)	115 (3.09)
4:2 FTS	87.6 (7.37)	108 (7.99)	105 (8.12)	99.7 (8.11)	105 (8.52)
6:2 FTS	113 (6.80)	113 (6.76)	110 (5.34)	105 (6.80)	105 (5.44)
8:2 FTS	118 (3.57)	101 (8.58)	96.4 (7.93)	108 (4.60)	103 (6.98)
FOSA	105 (12.5)	103 (7.55)	107 (6.24)	97.7 (10.6)	109 (5.68)
NMeFOSAA	105 (5.69)	92.2 (13.1)	87.0 (7.11)	91.8 (8.89)	98.0 (8.37)
NEtFOSAA	108 (7.59)	103 (9.82)	88.1 (9.60)	101 (10.5)	104 (6.61)
PFMPA	88.7 (6.82)	93.8 (9.95)	97.8 (13.1)	97.2 (9.27)	109 (5.00)
PFMBA	94.1 (11.1)	90.9 (10.4)	96.1 (9.65)	98.9 (6.79)	107 (6.54)
HFPO-DA	–	107 (9.78)	103 (10.2)	105 (11.1)	112 (5.38)
ADONA	101 (13.8)	104 (8.18)	88.0 (7.00)	83.8 (7.37)	89.8 (5.29)
PFEESA	103 (13.6)	95.2 (8.88)	97.2 (10.9)	94.9 (7.39)	101 (10.3)
9Cl-PF3ONS	108 (8.15)	96.7 (3.42)	81.7 (3.82)	95.0 (4.48)	94.2 (5.43)
11Cl-PF3OUdS	86.7 (8.10)	92.9 (8.10)	82.9 (2.81)	85.7 (3.71)	84.0 (9.17)
Capstone A	–	–	–	–	–
Capstone B	–	104 (7.55)	95.0 (14.0)	105 (9.55)	92.6 (11.2)

Infant Formula

	Average Recovery (RSD, %), n=9				
	Fortified Concentration (µg/kg)				
Analytes	0.010	0.025	0.050	0.10	0.25
^{13}C-TFA	–	95.8 (12.9)	102 (6.25)	110 (10.2)	110 (9.68)
PFPrA	–	96.6 (8.80)	99.2 (7.87)	92.0 (4.92)	116 (4.05)
PFBA	107 (7.01)	107 (8.41)	108 (4.84)	110 (4.96)	109 (4.42)
PFPeA	93.1 (6.70)	99.7 (9.51)	99.8 (9.22)	88.3 (7.39)	99.3 (6.81)
PFHxA	101 (8.37)	94.5 (10.6)	99.9 (7.70)	98.5 (4.85)	106 (7.37)
PFHpA	94.0 (9.15)	98.6 (8.38)	99.6 (7.19)	97.0 (8.02)	104 (6.90)
PFOA	97.2 (11.7)	102 (10.9)	103 (5.99)	105 (6.93)	110 (3.65)
PFNA	101 (5.60)	97.0 (5.33)	107 (4.99)	110 (5.07)	116 (4.24)
PFDA	91.4 (6.59)	89.9 (6.39)	110 (4.69)	116 (3.48)	113 (1.86)
PFUnA	99.1 (10.8)	86.8 (4.92)	105 (7.70)	116 (3.81)	112 (7.38)
PFDoA	82.7 (3.01)	82.2 (2.66)	96.4 (3.87)	106 (4.87)	106 (4.39)
PFTrDA	86.2 (3.82)	81.5 (1.67)	96.2 (6.82)	96.9 (4.46)	113 (5.98)
PFTeDA	81.8 (4.54)	80.8 (6.32)	89.8 (2.41)	90.1 (3.28)	106 (3.09)
TFMS	110 (7.01)	99.5 (8.05)	99.3 (7.09)	107 (9.75)	106 (10.4)
PFEtS	90.4 (12.1)	94.9 (6.25)	88.8 (5.44)	90.0 (7.63)	96.0 (5.53)
PFPrS	99.4 (9.37)	92.3 (8.05)	97.1 (4.87)	94.4 (7.57)	101 (4.53)
PFBS	101 (12.8)	107 (8.88)	98.2 (11.5)	94.6 (7.03)	109 (11.2)
PFPeS	111 (7.96)	106 (7.55)	108 (8.38)	106 (4.36)	111 (6.12)
PFHxS	85.5 (6.65)	89.1 (12.3)	96.1 (13.3)	96.2 (9.71)	105 (5.29)
PFHpS	87.9 (9.29)	88.0 (4.81)	90.9 (4.84)	89.1 (6.79)	94.4 (3.34)

Table II *(Continued)*

Infant Formula *(continued)*

	Average Recovery (RSD, %), n=9				
	Fortified Concentration (µg/kg)				
Analytes	**0.010**	**0.025**	**0.050**	**0.10**	**0.25**
PFOS	89.2 (9.65)	89.4 (10.7)	112 (7.14)	106 (7.94)	107 (6.53)
PFNS	86.9 (9.81)	82.7 (5.10)	108 (6.65)	107 (10.4)	108 (5.39)
PFDS	87.5 (11.9)	88.9 (9.25)	109 (7.57)	106 (9.44)	105 (8.17)
PFUdS	89.7 (10.2)	84.9 (5.13)	105 (9.17)	95.3 (10.4)	97.1 (6.65)
PFDoS	91.0 (9.86)	81.7 (6.58)	98.6 (10.6)	84.7 (8.43)	89.8 (9.51)
PFTrDS	80.5 (6.95)	83.6 (13.6)	94.6 (8.68)	84.6 (12.2)	93.0 (13.4)
4:2 FTS	101 (10.1)	113 (6.58)	108 (6.31)	112 (4.14)	112 (6.30)
6:2 FTS	111 (7.44)	99.8 (5.59)	110 (9.56)	116 (4.78)	118 (4.57)
8:2 FTS	89.4 (8.88)	86.2 (8.13)	107 (6.72)	117 (4.84)	115 (5.38)
FOSA	88.4 (8.80)	90.0 (7.86)	96.5 (13.6)	99.7 (7.60)	107 (12.2)
NMeFOSAA	89.0 (10.5)	87.9 (9.53)	101 (9.92)	102 (8.70)	103 (6.85)
NEtFOSAA	104 (9.71)	91.4 (9.41)	109 (7.39)	115 (4.19)	115 (4.33)
PFMPA	–	82.1 (4.74)	82.0 (3.76)	83.1 (4.58)	84.9 (4.63)
PFMBA	88.7 (12.1)	103 (12.5)	96.2 (8.93)	92.3 (9.42)	103 (6.87)
HFPO-DA	–	94.7 (13.7)	105 (7.55)	101 (5.29)	104 (9.62)
ADONA	117 (3.44)	108 (8.64)	108 (7.27)	104 (7.23)	108 (6.31)
PFEESA	99.7 (10.9)	110 (5.44)	106 (6.32)	100 (8.12)	109 (10.2)
9Cl-PF3ONS	84.8 (5.47)	87.8 (5.83)	83.6 (6.65)	84.4 (3.03)	86.3 (4.58)
11Cl-PF3OUdS	84.2 (7.68)	91.6 (8.41)	106 (5.69)	101 (7.79)	100 (5.06)
Capstone A	–	89.7 (10.4)	81.9 (7.72)	83.7 (6.37)	88.4 (9.29)
Capstone B	–	93.8 (11.3)	93.6 (12.4)	107 (11.8)	104 (12.7)

Real-World Sample Analysis

A total of 24 milk samples were collected from local grocery stores to assess PFAS contamination using the established workflow. Each sample was prepared in duplicate. The results revealed widespread presence of TFA, TFMS, PFBA, and PFHpA in the milk samples (Table IV). Notably, all tested soymilk samples contained high levels of PFPrA and PFBA. Long-chain compounds, including PFOA, PFOS, PFNA, PFDoA, and PFTeDA, were detected in some samples. A fluorotelomer sulfonic acid compound, 6:2 FTS, was the only PFAS identified aside from perfluoroalkyl carboxylic and sulfonic acids, and it was present in all four infant formula samples and some of the other milk samples. TFA concentrations were significantly higher and exceed the calibration range in some milk samples, necessitating sample dilution prior to extraction to obtain accurate quantification.

Table III: Measurement of 41 Targeted PFAS in Various Milk Matrices

	Concentration (µg/kg)										
	Ultrashort-Chain			Short-Chain		Long-Chain					Others
Milk Samples	TFA	PFPrA	TFMS	PFBA	PFHpA	PFOA	PFOS	PFNA	PFDoA	PFTeDA	6:2 FTS
Dairy Milk											
Whole Milk #1	2.3	nd	0.0049	nd	nd	nd	nd	nd	nd	nd	nd
Whole Milk #2	4.3	0.035	0.065	0.087	0.0093	0.0044	nd	nd	nd	nd	nd
Whole Milk #3	4.1	nd	<0.0040	0.038	<0.0040	0.0045	nd	nd	<0.0040	nd	0.011
Whole Milk #4	3.0	nd	0.0052	0.012	<0.0040	nd	nd	nd	nd	nd	nd
2% Reduced Fat Milk #1	3.5	nd	0.012	0.023	0.0045	0.0094	0.018	<0.0040	<0.0040	<0.0040	0.0043
2% Reduced Fat Milk #2	4.0	nd	0.0052	0.015	nd	nd	nd	nd	nd	nd	nd
Fat-Free Milk #1	3.6	nd	0.0055	0.011	nd	nd	nd	nd	nd	nd	nd
Fat-Free Milk #2	3.4	nd	0.0046	0.010	<0.0040	<0.0040	nd	nd	nd	nd	0.0041
Fat-Free Milk #3	2.4	nd	0.0076	nd	nd	nd	nd	nd	nd	nd	nd
Plant-Based Milk											
Almond Milk #1	1.8	nd	0.0043	0.017	nd	nd	nd	nd	nd	nd	nd
Almond Milk #2	2.2	nd	0.0070	0.021	<0.0040	<0.0040	nd	nd	<0.0040	nd	<0.0040
Almond Milk #3	5.3	nd	0.013	0.039	<0.0040	nd	nd	nd	nd	nd	nd
Oat Milk #1	7.2	nd	0.027	0.016	<0.0040	0.0052	0.0086	nd	nd	nd	0.055
Oat Milk #2	11	nd	0.021	0.019	nd	nd	nd	nd	nd	nd	0.0053
Soy Milk #1	24	0.52	0.016	0.21	<0.0040	nd	nd	nd	nd	nd	nd
Soy Milk #2	11	0.26	0.013	0.10	<0.0040	nd	nd	nd	nd	nd	nd
Soy Milk #3	5.6	0.088	0.016	0.069	nd	nd	nd	nd	nd	nd	nd
Coconut Milk #1	1.1	nd	0.0047	0.013	<0.0040	nd	nd	nd	nd	nd	nd
Coconut Milk #2	1.0	nd	0.0043	nd	<0.0040	0.0053	nd	nd	nd	nd	0.0053
Infant Formula											
Formula #1	1.0	nd	<0.0040	nd	nd	nd	nd	nd	nd	nd	0.0064
Formula #2	0.4	nd	<0.0040	nd	<0.0040	nd	nd	nd	nd	nd	0.0074
Formula #3	0.8	nd	<0.0040	0.012	<0.0040	<0.0040	nd	nd	nd	nd	0.0050
Formula #4	1.2	nd	0.0069	0.011	<0.0040	0.0050	nd	nd	nd	nd	0.012

nd = not detected

Conclusion

This study developed a simple, robust workflow for comprehensive PFAS analysis in various liquid milk matrices, successfully incorporating ultrashort-chain PFAS along with more commonly analyzed compounds. The optimized sample preparation protocol, combined with a sensitive LC method, enabled effective extraction and quantification of 41 PFAS with high accuracy and precision. The LC method leveraged a distinctive Ultra IBD Inert column, which features a polar-embedded alkyl stationary phase and an inert surface coating, providing enhanced retention for ultrashort-chain compounds and minimized analyte interaction to achieve increased sensitivity. Application of this workflow to commercial milk samples provided valuable insights into PFAS contamination across different milk sources. These findings highlight the importance of integrating ultrashort-chain PFAS into routine monitoring of PFAS in food products and offer a practical approach to support future food safety research and regulatory initiatives.

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Ultra IBD Inert HPLC Column

- Inert LC column technology reduces nonspecific binding of chelating analytes, enabling sensitive analysis and smooth integration of peaks.
- Ideal for the analysis of metal-sensitive compounds.
- Increased response and analyte recovery, allowing lower detection limits.
- Improved peak shape without passivation or mobile phase additives.
- Specialized columns for mixed polar and nonpolar compounds.
- Easy installation with standard fittings.

Catalog No.	Product Name	Units
9175312-T	Ultra IBD Inert HPLC Column, 3 µm, 100 mm x 2.1 mm	ea.

Ultra IBD HPLC Column

The Restek IBD is a polar-embedded column that acts as a strong hydrogen bonder and may be the most versatile column available today. With a unique polar group, this column is very retentive and selective for acids. It also provides symmetrical peak shape for strong bases. Restek's IBD is compatible with 100% aqueous mobile phases and can be used under reversed-phase or HILIC conditions to retain very polar, ionic compounds in highly organic mobile phases.

Catalog No.	Product Name	Units
9175362	Ultra IBD HPLC Column, 3 µm, 150 mm x 2.1 mm	ea.

PFAS 28 Calibration Standard

Contains:
11-chloroeicosafluoro-3-oxaundecane-1sulfonic acid (11Cl-PF3OUdS) (763051-92-9)
1*H*,1*H*,2*H*,2*H*-Perfluorodecane sulfonic acid (8:2 FTS) (39108-34-4)
1*H*,1*H*,2*H*,2*H*-Perfluorohexane sulfonic acid (4:2 FTS) (757124-72-4)
1*H*,1*H*,2*H*,2*H*-Perfluorooctane sulfonic acid (6:2 FTS) (27619-97-2)
4,8-dioxa-3*H*-perfluorononanoic acid (ADONA) (919005-14-4)
9-chlorohexadecafluoro-3-oxanonane-1-sulfonic acid (9Cl-PF3ONS) (756426-58-1)
2-(Heptafluoropropoxy)2,3,3,3tetrafluoropropionic acid (HFPO-DA) (13252-13-6)
N-ethylperfluoro-1-octanesulfonamidoacetic acid (NEtFOSAA)* (2991-50-6)
N-methylperfluoro-1-octanesulfonamidoacetic acid (NMeFOSAA)* (2355-31-9)
Perfluoro-1-decanesulfonic acid (PFDS) (335-77-3)
Perfluoro-1-nonanesulfonic acid (PFNS) (68259-12-1)
Perfluoro-1-octanesulfonamide (FOSA) (754-91-6)
Perfluoro-1-pentanesulfonic acid (PFPeS) (2706-91-4)
Perfluorobutanesulfonic acid (PFBS) (375-73-5)
Perfluorobutanoic acid (PFBA) (375-22-4)
Perfluorodecanoic acid (PFDA) (335-76-2)
Perfluorododecanoic acid (PFDOA) (307-55-1)
Perfluoroheptanesulfonic acid (PFHpS) (375-92-8)
Perfluoroheptanoic acid ((PFHpA) (375-85-9)
Perfluorohexanesulfonic acid (PFHxS)* (355-46-4)
Perfluorohexanoic acid ((PFHxA) (307-24-4)
Perfluorononanoic acid (PFNA) (375-95-1)
Heptadecafluorooctanesulfonic acid (PFOS)* (1763-23-1)
Perfluorooctanoic acid (PFOA)* (335-67-1)
Perfluoropentanoic acid (PFPeA) (2706-90-3)
Perfluorotetradecanoic acid (PFTeDA) (376-06-7)
Perfluorotridecanoic acid (PFTrDA) (72629-94-8)
Perfluoroundecanoic acid (PFUnA) (2058-94-8)
*Technical grade compound containing both branched and linear isomers; see certificate for details.

Catalog No.	Concentration	Solvent	Volume	Units
30734	1 µg/mL	Methanol (1 mM KOH)/2-Propanol (98:2)	1 mL/ampul	ea.

Empty Centrifuge Tubes

Catalog No.	Product Name	Units
25846	Empty Centrifuge Tubes, 50 mL, Polypropylene w/Cap	50-pk.