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Flame Grilled and Fluorinated - PFAS Analysis in Barbeque Foods Using a Miniaturized QuEChERS Workflow

Margot Lee, Kari Organtini

Waters Corporation, United States

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Abstract

From burgers and bratwurst to fresh watermelon and tomatoes, barbeques (BBQs) bring together a diverse range of foods that are staples of outdoor dining. While PFAS regulations and monitoring efforts have focused primarily on select food categories such as chicken, pork, and beef, much less is known about PFAS occurrence across the broader assortment of foods commonly found on the BBQ table. To provide a more comprehensive view of potential dietary exposure, this study evaluates PFAS concentrations in EU regulated meats, along with plant-based protein and fruit and vegetables, while demonstrating the robustness and versatility of analytical workflows across diverse food matrices.

An efficient workflow for the analysis of complex meat matrices is presented utilizing a quick, easy, cheap, effective, rugged, and safe (QuEChERS) extraction process to minimize PFAS internal standard consumption, decrease sample preparation time, and lessen matrix load on the analytical system— an important consideration as instrument sensitivity continues to improve.

The extraction workflow incorporated an automated solid-phase extraction (SPE) system capable of processing up to eight samples simultaneously in under 70 minutes. SPE cleanup is performed using dual-phase Oasis™ GCB/WAX for PFAS Analysis Cartridges, combining graphitized carbon black and weak anion exchange sorbents

to effectively remove matrix interference and enable precise, reproducible PFAS quantification across diverse food types. The CEN blend was chosen as it is the official European standard and designed for foods of plant origin, which are included in this study.

Benefits

- A streamlined PFAS workflow for sample preparation of complex matrices (protein and fat rich meats) with sensitive analysis on the Xevo™ TQ Absolute Mass Spectrometer to quantify at the sub-µg/kg levels required to meet the guidance and regulations from the FDA and EU
- Scaled-down QuEChERS workflow using a 2g sample with proportionally reduced, custom-weighed (miniaturized) QuEChERS salts
- Eliminates evaporation and reconstitution steps between QuEChERS and SPE cleanup, reducing sample preparation time and minimizing the risk of analyte loss while maintaining the sensitivity required for trace-level PFAS analysis
- Use of dual-phase Oasis for PFAS GCB/WAX Cartridges, combining two sorbents in one device, to streamline SPE, ensure cleanliness, and reduce false positives through QC-release testing for low residual PFAS
- The PFAS solution installation kit reduces the risk of system and solvent contamination affecting the analysis and thus providing confidence in the accuracy of results
- Provides a practical workflow for laboratories expanding PFAS testing beyond traditional meat matrices into processed foods, plant-based alternatives, fruits, and vegetables

Introduction

PFAS are persistent environmental contaminants that can accumulate in a variety of foods commonly consumed by humans, including meats and produce. As PFAS contamination continues to be identified across diverse food matrices, regulatory agencies have increased efforts to better understand dietary exposure and potential human health impacts. The European Union has established maximum levels for four PFAS compounds (PFOS, PFOA, PFNA, and PFHxS) in selected food categories, though allowable concentrations vary by food type.[1] The maximum levels can be seen in Table 1. In contrast, the United States currently has no federally established maximum limits for PFAS in food. The European Food Safety Authority (EFSA) has also established a tolerable weekly intake (TWI) of 4.4 ng/kg body weight for the sum of these four compounds, which are considered major contributors to PFAS levels observed in human serum.[2]

In addition to these regulated compounds, there are currently eight PFAS (PFOA, PFOS, PFNA, PFHxS, HFPO-DA (GenX), PFBS, PFBA, and PFHxA) for which toxicological reference values have been established and are used to evaluate potential health concerns associated with dietary exposure.[3] Although the FDA has not established maximum PFAS limits in food, the agency continues to monitor PFAS occurrence through targeted surveys, public reporting of testing results, and requests for information that may inform future guidance or regulatory actions.[3] Advances in LC-MS/MS technology now enable the detection of a broader range of PFAS at increasingly lower concentrations, supporting more comprehensive characterization of PFAS contamination across complex food matrices and improving our understanding of potential dietary exposure.

To demonstrate the capabilities of the Xevo TQ Absolute Mass Spectrometer and GCB/WAX for PFAS Cartridges for food testing, a workflow was developed for the determination of approximately 46 compounds across a variety of BBQ-related food matrices, including beef, pork, chicken, bratwurst (veal and pork), plant-based burger, watermelon, and tomato. Sample preparation was performed using a reduced-salt weight QuEChERS approach, followed by automated SPE using Oasis GCB/WAX for PFAS Cartridges on the PromoChrom SPE-03 System. Analysis was performed using the Xevo TQ Absolute Mass Spectrometer, enabling quantification at levels relevant to current and emerging regulatory interest. Method performance was evaluated through recovery studies at both 1.0µg/kg and 0.1µg/kg spike levels, demonstrating the ability to detect and quantify PFAS at concentrations relevant to existing European Union regulations. Additionally, the method achieved limits of quantification (LOQs) of 0.001 ug/kg for the EU 4 PFAS (listed in Table 1), meeting the analytical sensitivity recommended for fruits, vegetables, and baby food.

	µg/kg	PFOS	PFOA	PFNA	PFHxS	Max Sum
Meat of bovine animals, pig, and poultry[1]	Maximum levels[1]	0.3	0.8	0.2	0.2	1.3
	Method LOQs[4]	0.1	0.1	0.1	0.1	—
Fruit and vegetables[4]	Indicative levels[4]	0.01	0.01	0.005	0.015	—
	Method LOQs[4]	0.002	0.001	0.001	0.004	—

Table 1. Maximum levels set in EU Commission Regulation 2022/2388 for food of animal origin[1] and indicative levels proposed in EU Commission Recommendation 2022/1431 for fruits and vegetables[4] with LOQs required by the recommendation for the analytical methods detailed.

Experimental

Meat and produce samples were purchased from a local grocery store. All meat samples were purchased fresh, with chicken and beef in ground form, pork and bratwurst as sausage, and the veggie burger as frozen patties. Each meat sample was blended in a food processor with dry ice until a uniform mixture was achieved. Watermelon was purchased pre-cut while tomatoes were purchased whole. Both produce samples were then prepared separately by homogenization in a blender.

All standards were purchased from Wellington Laboratories, Cambridge Isotope Laboratories, and LGC Standards. Table 2 lists the standard mix stock solutions used.

Name of Commercial Standard	Purpose	Vendor
MPFAC-HIF-ES	Extracted Internal Standard	Wellington Laboratories
MPFAC-HIF-IS	Non-extracted Internal Standard	Wellington Laboratories
PFAC-mix	Native Standard Mix	Wellington Laboratories
M_2 6:2 FTS	Extracted Internal Standard	Wellington Laboratories
13C3 PFDoDS	Extracted Internal Standard	LGC Standards
13C6 PFTrDA	Extracted Internal Standard	Cambridge Isotope Laboratories
13C3 PFTrDS	Extracted Internal Standard	LGC Standards
M_2 Capstone B (M_2 6:2 FTAB)	Extracted Internal Standard	Wellington Laboratories

Table 2. Native and isotope labeled standards used for analysis.

A native PFAS mix stock solution was prepared in methanol and was used for serial dilutions. An extraction internal standard (EIS) solution was prepared in methanol and was used to spike samples prior to extraction. A mixture of EIS and non-extracted internal standards (NIS) was prepared in a solution of ammonium hydroxide, water, acetic acid, and methanol, which also was used as the diluent for the calibration standards. This solvent composition was selected to match the final composition of the SPE eluates, minimizing the solvent mismatch between calibration standards and sample extracts. Following extraction, the NIS solution was added to each sample extract prior to LC-MS/MS analysis.

A ten-point solvent calibration curve was prepared and used for quantification of all food sample extracts. For samples spiked at 1 µg/kg, the calibration range was 10 – 10,000 ng/L (0.01-10 ng/mL; 0.025 µg/kg – 25 µg/kg), while samples spiked at 0.1 µg/kg were quantified using a calibration range of 5 – 5,000 ng/L (0.005-5 ng/mL; 0.0125 – 12.5 µg/kg).

Concentrations were reported in µg/kg. Because there are no representative meat or produce reference samples that could be used as blanks, the blank samples were CEN blend QuEChERS salts that were spiked with EIS. Percent recoveries were calculated by subtracting the concentration in unspiked sample from that measured in the corresponding pre-extraction native-spiked sample, dividing the blank-corrected

concentration by the expected spike concentration, and multiplying by 100%.

Sample Preparation

All native spiked and unspiked samples and blanks were prepared in triplicate. The LC-MS/MS acquisitions were also run in triplicate. Sample preparation was performed using a reduced QuEChERS workflow with custom-weighed CEN Blend Pouches followed by SPE on the PromoChrom SPE-03 Gen 4 Automated SPE System. The sample preparation can be seen in Figure 1, and the SPE program is described in Table 3.

1	• Meat: Cryo-grind with dry ice, allow to sublimate • Fruit/Veg: Blend to uniform liquid
2	• Weigh 2 g sample and add to PP tube
3	• Spike samples with extracted internal standards and allow to sit for 2–3 hours
4	• Add 10 mL LC-MS grade Acetonitrile and vortex
5	• Add custom weighed CEN QuEChERS packet, and vortex
6	• Centrifuge 5 min at 4,000 RPM
7	• Transfer 10 mL supernatant to new 50 mL PP tube
8	• Dilute to 50 mL with LC-MS grade water, verify pH ≤ 6, adjust if needed
9	• Complete SPE with Oasis GCB/WAX dual phase Cartridge on PromoChrom SPE-03
10	• Post spike non-extracted internal standards into 5 mL elute and add 25 µL of acetic acid, transfer to injection vial, analyze on Xevo TQ-Absolute System

Figure 1. Sample preparation procedure.

Automated SPE Method for PFAS in a 2 g Sample Post-QuEChERS Extract

Action	Inlet 1	Inlet 2 (ratio)	Flow	Volume
Elute W2	Solvent 5	—	8	15
Elute W1	Solvent 3	—	8	5
Add Sample W1	Sample	—	5	75
Rinse	Solvent 2	Air (20%)	45	2.5
Add Sample W1	Sample	—	5	5
Rinse	Solvent 2	Air (20%)	45	5
Add Sample W1	Sample	—	5	5
Rinse	Solvent 2	Air (20%)	45	5
Add Sample W1	Sample	—	5	5
Shake	—	Time based	—	20 s
Rinse	Solvent 4	Air (20%)	45	1.3
Add Sample W1	Sample	—	5	3
Rinse	Solvent 4	Air (20%)	45	5
Add Sample W2	Sample	—	5	5
Shake	—	Time based	—	20 s
Air Purge W2	Air	—	5	3
Add Sample W2	Sample	—	5	5
Blow N2	—	Time based	—	3 min
Rinse	Solvent 5	Air (20%)	45	1.3
Collect 1	Sample	—	1	3
Rinse	Solvent 5	Air (20%)	45	5
Air Purge R	Air	—	20	5
Shake	—	Time based	—	15 s
Clean	Sample	—	30	5
Clean	Sample	—	30	5
Collect 1	Sample	—	1	15

Table 3. PromoChrom SPE method for extraction of PFAS in meat and produce.

LC Conditions

UPLC system:	ACQUITY™ UPLC™ I-Class PLUS System with PFAS Analysis Kit
Mobile phase A:	2 mM Ammonium Acetate in Water
Mobile phase B:	2 mM Ammonium Acetate in Acetonitrile
Column:	Analytical column: ACQUITY Premier BEH™ C_{18} Column, 2.1 x 50 mm, 1.7 µm (p/n: 186009452) Isolator column: Atlantis™ Premier BEH C_{18} AX Column, 2.1 x 50 mm, 5.0 µm (p/n: 186010926)
Vials:	700 µL Polypropylene Screw Cap Vials 700 µL (p/n: 186005219)
Column temperature:	35 ˚C
Sample temperature:	8 ˚C
Injection volume:	2 µL for 1µg/kg spiked samples, and 10 µL for 0.1µg/kg spiked samples

Gradient Table

Time (min)	Flow Rate (mL/min)	%A	%B	Curve
0	0.3	95	5	initial
0.5	0.3	75	25	6
3	0.3	50	50	6
6.5	0.3	15	85	6
7	0.3	5	95	6
8.5	0.3	5	95	6
9	0.3	95	5	6
11	0.3	95	5	6

MS Conditions

MS system:	Xevo TQ Absolute Mass Spectrometer
Ionization mode:	ESI-, (ESI+ for Capstones A and B)
Capillary voltage:	0.5 kV
Source temperature:	100 °C
Desolvation temperature:	350 °C
Desolvation flow:	900 L/hr
Cone flow:	150 L/hr
MRM transitions:	See Appendix for full MRM Details

Data Management

Software:	waters_connect™ for Quantitation Software

Results and Discussion

Linearity and Calibration

Calibration curves were prepared in solvent using ten calibration levels and analyzed throughout each sequence alongside spiked samples. Linear regression with 1/x weighting was used for quantification. Linearity was achieved for all four EU-regulated PFAS analytes, as shown in Figure 2.

The calibration range was selected to support quantification of PFAS at concentrations relevant to current European Union maximum levels for food.[1] The lowest calibration standard (5 ng/L) provided sufficient sensitivity to support quantification of the regulated PFAS compounds in meat and produce following the miniaturized QuEChERS extraction procedure.

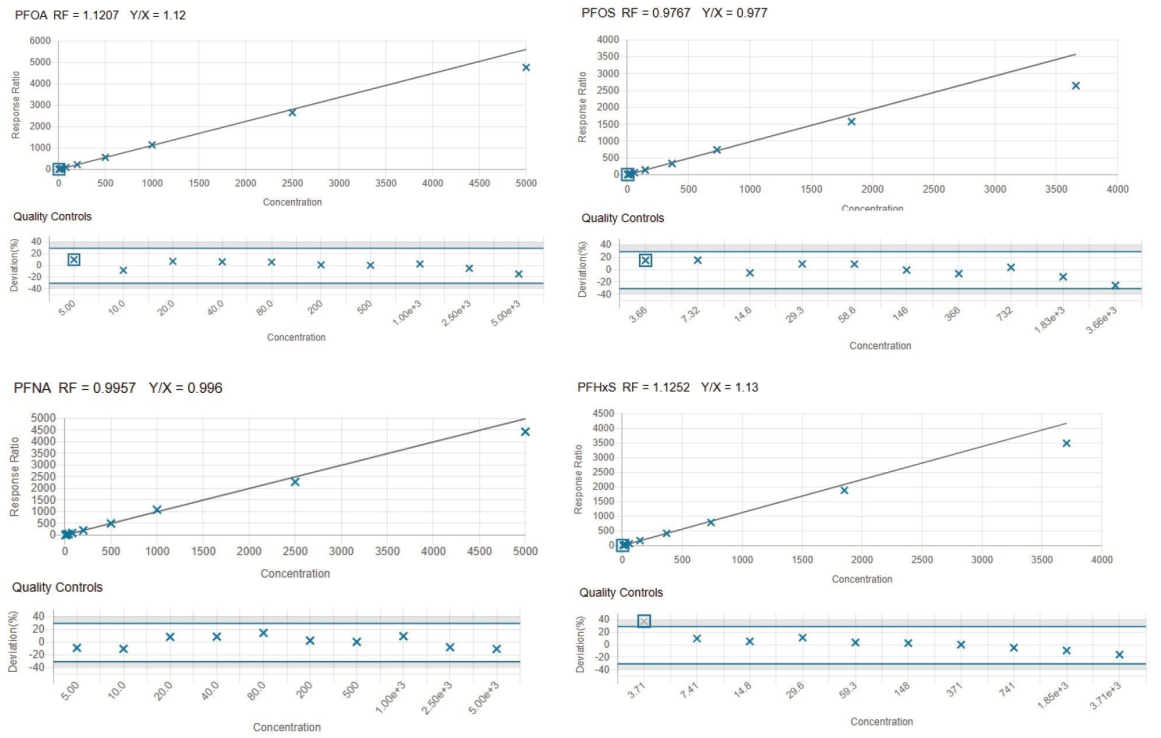

Figure 2. Calibration curves and residuals plots of the EU mandatory PFAS (PFOS, PFOA, PFNA, and PFHxS).

Chromatography

Representative chromatograms of the four EU-regulated PFAS at the lowest calibration level (5 ng/L) are shown in Figure 3. All analytes produced well-defined, symmetrical peaks with consistent retention times and minimal background interference, demonstrating chromatographic performance suitable for quantification across the calibration range.

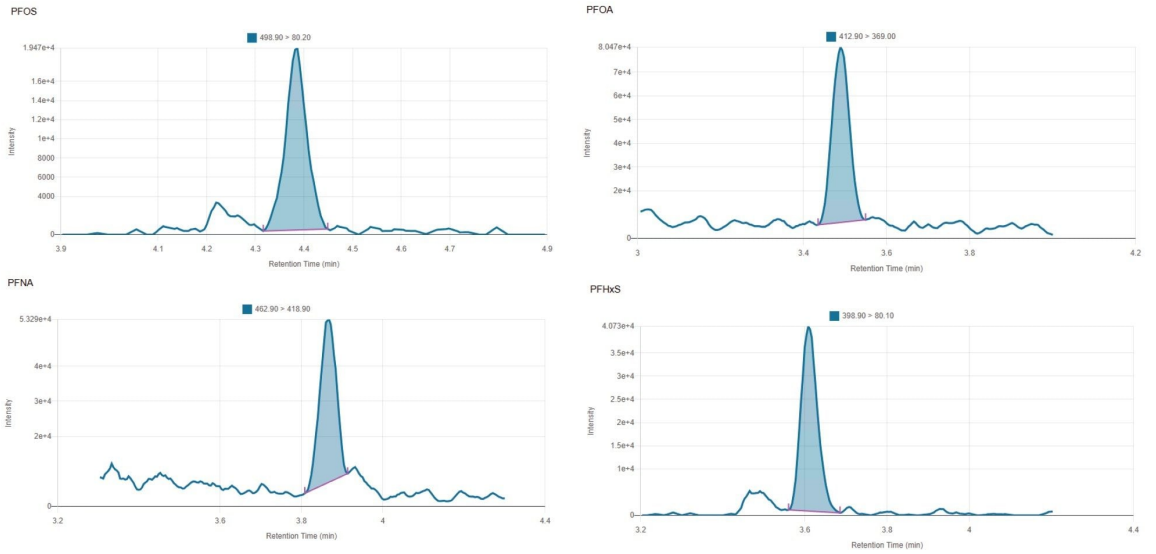

Figure 3. Representative chromatograms of the EU-regulated PFAS (PFOS, PFOA, PFNA, PFHxS) at the lowest calibration level (Cal 1, 5ng/L).

Most analytes demonstrated recoveries within the 70–130% range at both the 1 µg/kg and 0.1 µg/kg PFAS fortification levels, as shown in Table 4, highlighting the broad applicability of the method across a diverse range of PFAS analytes and food matrices. Importantly, the four PFAS currently regulated by the European Union (PFOS, PFNA, PFOA, PFHxS) met the EURL POPs recommended recovery criterion of 80-120%[5] at 0.1 µg/kg, supporting the robustness of the method for compounds currently subject to regulatory scrutiny.

While recoveries were generally comparable between the two fortification levels, greater variability was observed for some analytes at 0.1 µg/kg. This increased variability is expected at lower fortification levels; however the method maintained acceptable recovery and demonstrated reliable performance at these trace concentrations. Several fluorotelomer-based compounds exhibited greater concentration-dependent variability, likely reflecting these analytical effects rather than changes in extraction efficiency.

Overall, acceptable recoveries were achieved across the meat and produce samples evaluated, demonstrating the applicability of the extraction and SPE workflow to challenging food samples. The results demonstrate that the method is capable of reliable PFAS quantitation at both µg/kg and sub-µg/kg concentrations, supporting its suitability for trace-level PFAS analysis in foods relevant to current regulatory and monitoring efforts. Previous work demonstrated that Capstone A may be lost during the SPE procedure.[6] Recovery of Capstone A was consistently lower than that of Capstone B, likely because no compound-specific isotopically labeled internal standard was available at the time of experimentation. Instead, the isotopically labeled Capstone B analogue

was used as a surrogate internal standard for both analytes, which may not fully compensate for differences in analyte behavior experienced by Capstone A throughout the workflow. Despite this limitation, these results demonstrate that the workflow provides reliable extraction, cleanup, and quantitation for a broad range of PFAS in complex food matrices, including meats and produce commonly associated with barbecue meals, while maintaining performance at concentrations relevant to current regulatory requirements.

Compound	Spike Concentration	Veggie Burger % Recovery	Bratwurst % Recovery	Beef % Recovery	Chicken % Recovery	Pork % Recovery	Watermelon % Recovery	Tomato % Recovery
PFBA	1 ng/g	92	103	100	98	101	85	89
	0.1 ng/g	192	156	130	156	157	145	100
PFPeA	1 ng/g	97	108	104	100	109	92	96
	0.1 ng/g	125	115	107	119	108	103	103
PFHxA	1 ng/g	83	105	91	127	101	84	79
	0.1 ng/g	72	63	63	56	53	55	64
PFHpA	1 ng/g	93	108	97	102	120	83	86
	0.1 ng/g	105	109	110	108	93	99	99
PFOA	1 ng/g	99	102	105	100	113	86	100
	0.1 ng/g	116	119	111	107	87	94	60
PFNA	1 ng/g	104	116	114	101	108	89	90
	0.1 ng/g	102	123	112	107	92	95	95
PFDA	1 ng/g	109	112	102	95	85	88	87
	0.1 ng/g	105	113	116	115	94	97	97
PFUnDA	1 ng/g	108	125	109	104	104	94	93
	0.1 ng/g	93	99	104	103	89	90	90
PFDoDA	1 ng/g	99	112	99	103	109	88	88
	0.1 ng/g	87	90	103	104	87	92	92
PFBS	1 ng/g	100	109	102	99	102	87	90
	0.1 ng/g	103	115	101	105	94	94	85
PFPeS	1 ng/g	87	98	94	99	104	85	88
	0.1 ng/g	91	101	104	69	78	98	98
PFHxS	1 ng/g	90	106	98	91	100	85	87
	0.1 ng/g	115	102	109	73	88	107	107
PFHpS	1 ng/g	89	123	112	99	87	92	90
	0.1 ng/g	77	146	96	95	85	90	90
PFOS	1 ng/g	95	104	109	96	97	91	90
	0.1 ng/g	82	77	110	88	63	89	89
PFNS	1 ng/g	99	97	111	99	108	95	96
	0.1 ng/g	90	129	98	92	87	83	83
PFDS	1 ng/g	100	78	100	102	103	88	87
	0.1 ng/g	94	129	97	107	97	89	89
PFDoDS	1 ng/g	83	89	79	77	79	73	67
	0.1 ng/g	92	90	103	98	95	98	98
PFEESA	1 ng/g	95	116	106	104	108	92	93
	0.1 ng/g	85	95	102	99	95	88	88
PFMPA	1 ng/g	105	114	104	103	112	87	93
	0.1 ng/g	93	90	99	97	93	98	98
PFMBA	1 ng/g	97	110	106	103	104	88	95
	0.1 ng/g	92	88	97	94	83	93	93
GenX	1 ng/g	97	108	108	101	102	88	91
	0.1 ng/g	105	106	113	107	83	105	105
ADONA	1 ng/g	99	109	101	100	95	87	91
	0.1 ng/g	98	99	107	97	76	92	92

Compound	Spike Concentration	Veggie Burger % Recovery	Bratwurst % Recovery	Beef % Recovery	Chicken % Recovery	Pork % Recovery	Watermelon % Recovery	Tomato % Recovery
FOSA	1 ng/g	97	108	100	98	96	86	88
	0.1 ng/g	93	97	101	102	92	95	93
NMeFOSA	1 ng/g	98	107	111	110	110	97	94
	0.1 ng/g	104	110	100	119	105	114	114
NEtFOSA	1 ng/g	123	105	94	111	110	94	98
	0.1 ng/g	92	93	103	103	101	97	97
N-MeFOSAA	1 ng/g	95	109	105	93	105	102	95
	0.1 ng/g	96	101	109	106	104	101	101
N-EtFOSAA	1 ng/g	96	109	94	101	99	84	84
	0.1 ng/g	85	92	95	95	74	103	103
NMeFOSE	1 ng/g	131	114	113	114	107	93	98
	0.1 ng/g	90	93	92	100	100	97	97
NEtFOSE	1 ng/g	88	173	107	98	103	88	88
	0.1 ng/g	80	93	100	98	98	94	94
NFDHA	1 ng/g	100	109	102	104	106	91	93
	0.1 ng/g	91	94	99	92	86	89	89
9Cl-PF3ONS	1 ng/g	93	111	104	101	100	92	90
	0.1 ng/g	78	109	90	89	82	78	78
11Cl-PF3OUdS	1 ng/g	90	120	94	92	92	88	87
	0.1 ng/g	91	133	104	97	95	93	93
4:2 FTS	1 ng/g	118	122	108	109	101	57	76
	0.1 ng/g	22	71	100	80	78	50	50
6:2 FTS	1 ng/g	89	98	96	99	98	83	88
	0.1 ng/g	132	130	128	131	171	122	101
8:2 FTS	1 ng/g	97	105	106	98	101	87	85
	0.1 ng/g	106	94	110	105	85	101	92
3:3 FTCA	1 ng/g	91	97	94	100	92	77	76
	0.1 ng/g	78	85	87	87	44	78	78
5:3 FTCA	1 ng/g	96	101	100	100	98	83	78
	0.1 ng/g	80	90	91	76	103	71	63
7:3 FTCA	1 ng/g	102	112	98	97	109	87	82
	0.1 ng/g	97	103	113	90	160	78	78
PFTrDS	1 ng/g	70	88	83	76	80	74	66
	0.1 ng/g	101	106	109	109	105	108	108
PFTreDA	1 ng/g	100	112	106	104	107	93	97
	0.1 ng/g	80	89	104	105	97	92	92
PFTriDA	1 ng/g	93	102	82	85	80	73	72
	0.1 ng/g	209	121	124	89	51	103	103
PFUnDA	1 ng/g	108	129	109	104	104	94	93
	0.1 ng/g	93	99	104	103	89	90	90
PFUnDS	1 ng/g	60	128	79	91	101	72	78
	0.1 ng/g	24	58	90	80	82	92	92
Capstone A	1 ng/g	36	53	14	23	65	33	51
	0.1 ng/g	27	13	30	19	12	33	35
Capstone B	1 ng/g	159	132	89	108	121	95	75
	0.1 ng/g	119	100	105	71	60	107	107

Table 4. Percent recovery of each PFAS spiked into meats, with recoveries calculated at 1n ng/g and 0.1 µg/kg spike level.

Table 5 summarizes the PFAS detected in each sample. Among the four PFAS currently regulated by the European Union (PFOS, PFOA, PFNA, and PFHxS), detections were infrequent and all measured concentrations remained well below the current EU maximum levels for meat and produce. PFOA and PFNA were detected sporadically across several matrices at low concentrations, while PFHxS was detected only in bratwurst and chicken, and PFOS was detected only in beef. The combined concentration of the four regulated PFAS remained low across all samples, with no matrix approaching the current European regulatory limits.

Several non-regulated short-chain PFAS and fluorotelomer compounds were also detected. PFBS was observed

primarily in the veggie burger and bratwurst, while 4:2 FTS was detected in the veggie burger, watermelon, and tomato. Watermelon exhibited the highest total PFAS concentration (0.213 µg/kg), driven predominantly by 4:2 FTS rather than the regulated PFAS. Although this study was not designed to identify contamination sources, fluorotelomer compounds such as 4:2 FTS have been associated with environmental contamination and may reflect exposure through agricultural inputs or other environmental pathways.

Overall, these findings demonstrate that commercially available meat and produce samples contained relatively low PFAS concentrations, with regulated PFAS detected only sporadically and at trace levels. At the same time, the broader analyte panel provided additional insight into the occurrence of short-chain and emerging PFAS beyond those currently regulated, highlighting the value of comprehensive PFAS monitoring in food.

Compound	Veggie Burger (µg/kg)	Bratwurst (µg/kg)	Beef (µg/kg)	Chicken (µg/kg)	Pork (µg/kg)	Watermelon (µg/kg)	Tomato (µg/kg)
PFPeA	ND	ND	ND	0.037	0.037	0.029	0.038
PFHpA	<LOQ	<LOQ	<LOQ	<LOQ	0.052	ND	ND
PFOA	0.014	<LOQ	<LOQ	<LOQ	ND	ND	ND
PFNA	<LOQ	<LOQ	<LOQ	<LOQ	ND	ND	<LOQ
PFDA	ND	<LOQ	<LOQ	<LOQ	ND	ND	ND
PFUnDA	<LOQ	<LOQ	<LOQ	<LOQ	ND	ND	ND
PFTriDA	ND	ND	<LOQ	<LOQ	ND	ND	ND
PFTreDA	<LOQ	<LOQ	<LOQ	<LOQ	ND	ND	ND
PFBS	0.047	0.024	ND	<LOQ	ND	ND	ND
PFHxS	ND	0.013	ND	<LOQ	ND	ND	ND
PFOS	ND	ND	<LOQ	ND	ND	ND	ND
NMeFOSA	ND	<LOQ	ND	<LOQ	ND	0.019	ND
4:2 FTS	0.042	ND	ND	ND	ND	0.164	0.021
Total combined	**0.111**	**0.052**	**0.008**	**0.047**	**0.089**	**0.212**	**0.059**
Sum 4 regulated	**0.019**	**0.022**	**0.005**	**0.006**	**0.00**	**0.00**	**0.00**

Table 5. Concentrations in µg/kg of PFAS detected in meats and produce following blank correction.

Figures 4 and 5 demonstrate the presence of the four compounds regulated by the EU and Figures 6 and 7 demonstrate the eight compounds that have been evaluated in food by the FDA in the meat and produce evaluated. While the U.S. doesn't currently have regulatory limits for these in food, the FDA uses these compounds for risk assessment and monitoring. This broader panel reinforces the same overall trends, while capturing additional short-chain and emerging PFAS. Trace levels of PFOA and PFNA were detected in the veggie burger and tomato samples. Although these concentrations were well below current EU maximum limits, they exceeded the EU Recommendation (EU) 2022/1431[4] monitoring guidance level of 0.001 µg/kg,

highlighting the capability of the method to detect PFAS at concentrations relevant to ongoing European monitoring efforts.

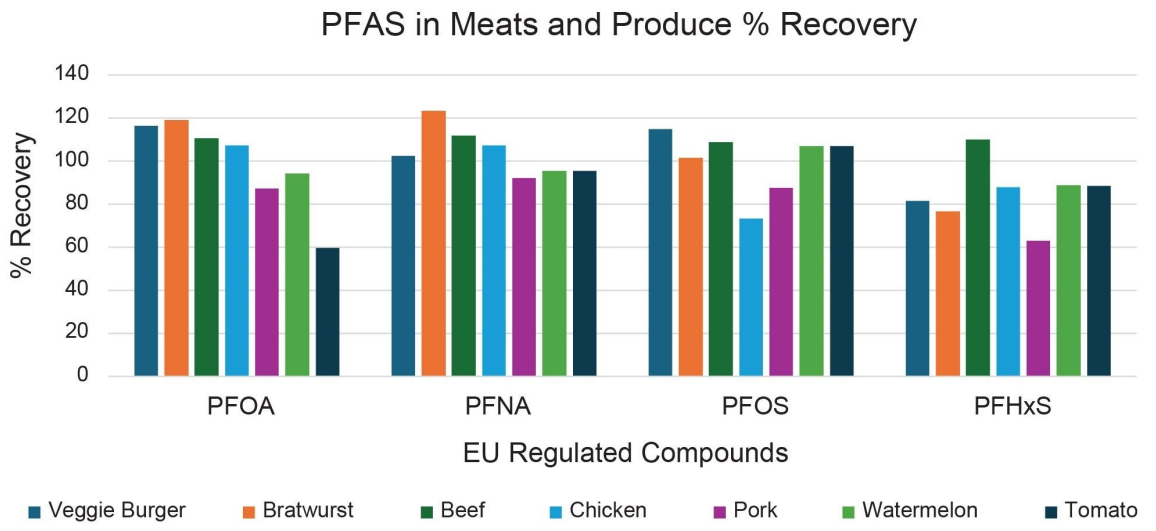

Figure 4. Percent recovery for the four PFAS compounds regulated in food by the EU.

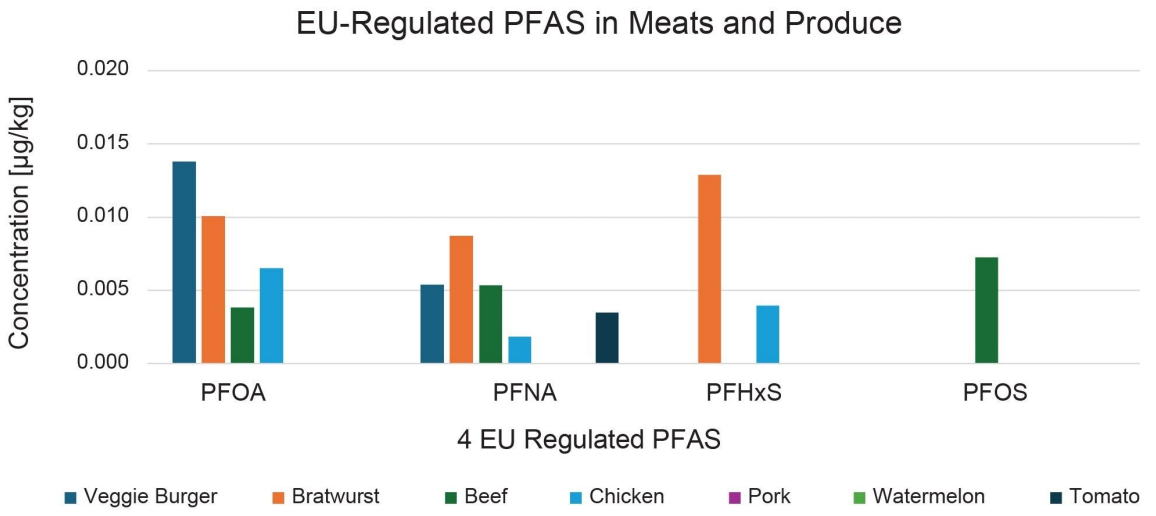

Figure 5. Calculated concentration in µg/kg for the four PFAS compounds regulated in food by the EU.

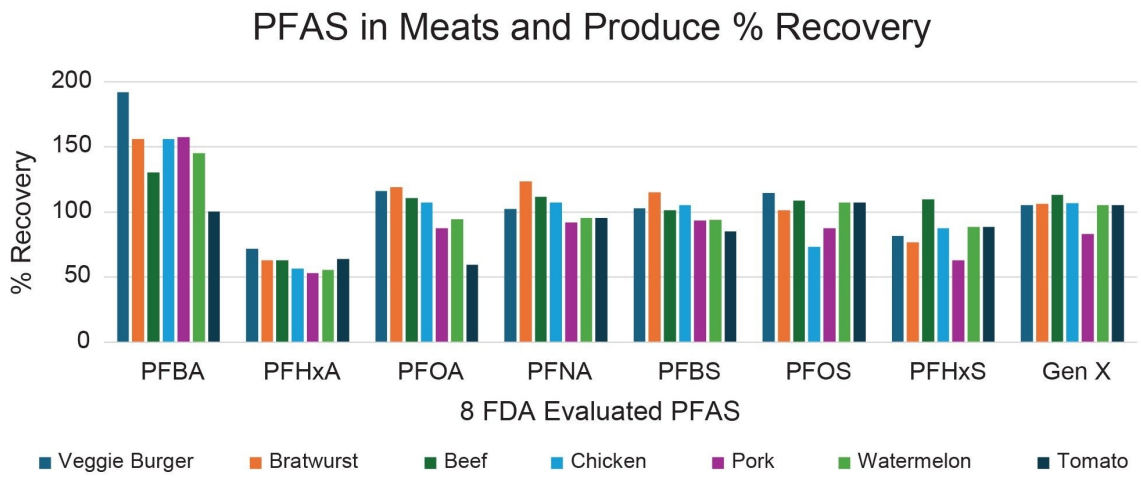

Figure 6. Percent recovery for the eight PFAS compounds evaluated in food by the FDA, including the four EU regulated PFAS. The elevated PFBA recoveries observed may reflect contributions from background contamination, as PFBA is a ubiquitous environmental and laboratory contaminant.

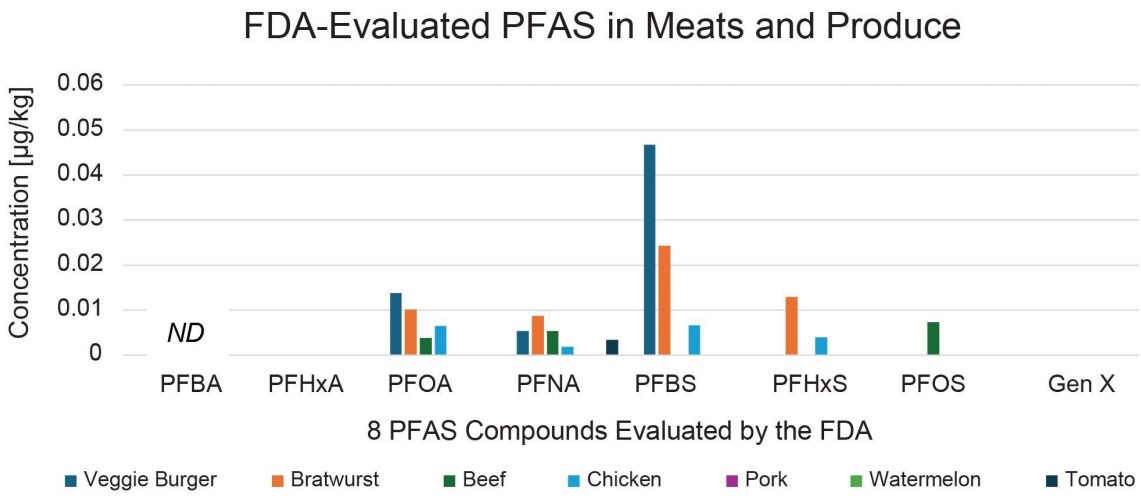

Figure 7. Eight PFAS compounds evaluated in food by the FDA, including the four EU regulated PFAS. No US regulatory limits have been set as of the time of this publication (July 2026).

Conclusion

A reduced-volume QuEChERS workflow provided a simple and efficient sample preparation approach while minimizing sample requirements, reducing consumption of costly PFAS standards (as less volume of standards are needed for smaller sample sizes), and decreasing overall preparation time. Coupled with the enhanced sensitivity of the Xevo TQ Absolute Mass Spectrometer, the method enabled reliable analysis at concentrations as low as the 0.1µg/kg level regulated by the European Union without requiring larger sample masses.

For more complex matrices, automated SPE using the PromoChrom SPE-03 System in combination with the Oasis GCB/WAX for PFAS Cartridges provided efficient and reproducible extraction of PFAS from higher fat and protein foods. Automation of the SPE workflow also reduces hands-on time and increases laboratory throughput.

The method supports the analysis of PFAS currently regulated by the EU, compounds under evaluation by the FDA, and additional PFAS of emerging interest, including Capstone A and Capstone B. Recovery of Capstone A was consistently lower than that of Capstone B, likely attributable to the absence of an isotopically labeled internal standard specific to Capstone A. Quantitation of both analytes was performed using the Capstone B mass-labeled internal standard, which may not fully compensate for differences in extraction efficiency and matrix effects experienced by Capstone A.

Acceptable method performance was demonstrated at both 1 µg/kg and the more challenging 0.1 µg/kg fortification levels, supporting reliable quantification at concentrations relevant to current regulatory guidance. Across the food samples analyzed, PFAS occurrence was generally low, with detections consisting of mostly short-chain PFAS and only limited detections of regulated compounds at trace concentrations. These findings further demonstrate that PFAS monitoring should encompass a broad range of food matrices including meats, processed foods, plant-based alternatives, and produce.

As PFAS surveillance continues to expand, the reduced-volume QuEChERS workflow combined with automated SPE using Oasis GCB/WAX for PFAS Cartridges provides a robust, high-confidence solution for laboratories implementing or expanding PFAS testing. By reducing sample preparation time, minimizing solvent and PFAS standard consumption, and supporting reliable analysis across diverse food matrices, the workflow offers an efficient approach to high-confidence PFAS monitoring for routine laboratory food testing. Ultimately, this work demonstrates that even complex food matrices, including foods commonly seen in BBQs, can be analyzed using streamlined sample preparation and enhanced sensitivity of the Xevo TQ Absolute Mass Spectrometer.

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Compound	CAS Number	Internal Standard	CV	CE	Expected RT	Precursor Mass (*m/z*)	Product Mass (*m/z*)	Product Mass 2 (*m/z*)
11Cl-PF3OUdS	763-051-92-9	M8 PFOS	30	30	5.35	630.9	450.80 (Quan)	83
3:3 FTCA	356-02-5	None	5	40	2.1	241	176.90 (Quan)	116.9
4:2 FTS	757124-72-4	M2 4:2 FTS	15	35	2.7	326.9	307.00 (Quan)	81.1
5:3 FTCA	914637-49-3	M5 PFHxA	5	25	3.8	340.9	237	216.90 (Quan)
6:2 FTS	27619-97-2	M2 6:2 FTS	15	30	3.3	426.9	407	80.80 (Quan)
7:3 FTCA	812-70-4	M5 PFHxA	10	22	5	440.9	337	316.90 (Quan)
8:2 FTS	39108-34-4	M2 8:2 FTS	15	35	4	526.9	506.8	80.80 (Quan)
9Cl-PF3ONS	756426-58-1	M8 PFOS	15	25	4.6	530.9	350.90 (Quan)	83
ADONA	919005-14-4	M3 GenX	10	25	3.2	376.9	85	251.00 (Quan)
FHxSA	41997-13-1	M8 FOSA	30	25	5.96	398	169	78.10 (Quan)
FOSA	754-91-6	M8 FOSA	40	30	5.9	497.9	78.20 (Quan)	
GenX (HFPO-DA)	13252-13-6	M3 GenX	5	35	2.3	285	169.00 (Quan)	119
N-EtFOSAA	2991-50-6	D5 N-EtFOSAA	15	20	5	584	525.9	418.80 (Quan)
N-MeFOSAA	2355-31-9	D3 N-MeFOSAA	35	25	4.5	569.9	418.90 (Quan)	219.1
NEtFOSA	4151-50-2	dNEtFOSA	5	25	7.04	525.9	168.90 (Quan)	218.9
NEtFOSE	1691-99-2	d9 NEtFOSE	15	15	6.91	630	59.00 (Quan)	
NFDHA	151772-58-6	M5 PFHxA	5	10	2.8	295	200.90 (Quan)	84.9
NMeFOSA	31506-32-8	dNMeFOSA	40	30	6.75	511.9	218.9	168.90 (Quan)
NMeFOSE	24448-09-7	d7 NMeFOSE	15	15	6.6	616	59.00 (Quan)	
PFBA	375-22-4	M4 PFBA	10	20	2.05	212.9	169.00 (Quan)	19
PFBS	375-73-5	M3 PFBS	15	30	2.7	298.9	80.10 (Quan)	99.1
PFDA	335-76-2	M6 PFDA	14	15	4.2	512.9	468.90 (Quan)	219
PFDoDA (PFDoA)	307-55-1	M PFDoDA	30	25	4.9	612.9	568.90 (Quan)	169
PFDoDS (PFDoS)	79780-39-5	$^{13}C_3$ PFDoDS	40	55	5.8	699.1	80.00 (Quan)	99
PFDS	335-77-3	M8 PFOS	25	40	5.1	598.9	80.20 (Quan)	99.1
PFEESA	113507-82-7	M5 PFHxA	15	20	2.9	314.9	134.90 (Quan)	82.9
PFHpA	375-85-9	M4 PFHpA	15	15	3.1	362.9	319.00 (Quan)	169
PFHpS	375-92-8	M8 PFOS	15	35	4.1	448.9	80.20 (Quan)	99.1
PFHxA	307-24-4	M5 PFHxA	5	20	2.6	312.9	269.0 (Quan)	
PFHxS	355-46-4	M3 PFHxS	10	35	3.7	398.9	80.10 (Quan)	99.1
PFMBA	863090-89-5	M5 PFPeA	10	10	2.54	278.9	84.90 (Quan)	
PFMPA	377-73-1	M5 PFPeA	23	10	2.15	228.9	84.90 (Quan)	
PFNA	375-95-1	M9 PFNA	10	15	3.8	462.9	418.90 (Quan)	219
PFNS	68259-12-1	M8 PFOS	20	40	4.8	548.9	80.20 (Quan)	99.2
PFOA	335-67-1	M8 PFOA	10	15	3.5	412.9	369.00 (Quan)	169
PFOS	1763-23-1	M8 PFOS	15	40	4.4	498.9	80.20 (Quan)	99.1
PFPeA	2706-90-3	M5 PFPeA	10	20	2.4	262.9	219.00 (Quan)	19
PFPeS	2706-91-4	M3 PFHxS	10	30	3.45	348.9	80.10 (Quan)	99.1
PFTreDA (PFTeDA)	376-06-7	M2 PFTreDA	10	25	5.6	712.9	668.90 (Quan)	169
PFTriDA (PFTrDA)	72629-94-8	$^{13}C_6$ PFTrDA	5	30	5.3	662.9	618.90 (Quan)	169
PFUnDA (PFUnA)	2058-94-8	M7 PFUnDA	25	20	4.6	562.9	518.90 (Quan)	269
Capstone A	80475-32-7	M2 Capstone B	44	34	4.4	529.1	58.00 (Quan)	440
Capstone B (6:2 FTAB)	34455-29-3	M2 Capstone B	92	32	3.96	571.1	103.95 (Quan)	439.97
PFTrDS	72629-96-0	$^{13}C_3$PFTrDS	40	54	6.1	749.1	80.00 (Quan)	99
PFUnDS	749786-16-1	M2 10:2 FTS	40	52	5.45	649.1	80.00 (Quan)	99
PFHxA	307-24-4	M5 PFHxA	5	10	3.7	312.9	269.00 (Quan)	

Appendix Table 1. MS method conditions for PFAS included in method. "(Quan)" indicates MRM used as quan ion.

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MassTrak ACQUITY UPLC I-Class PLUS/Xevo TQ Absolute XR IVD System <https://www.waters.com/nextgen/global/products/in-vitro-diagnostics-solutions/lc-ms-ms-ivd-systems-portfolio/masstrak-acquity-uplc-i-class-plus-xevo-tq-absolute-xr-ivd-system.html>

waters_connect for Quantitation <https://www.waters.com/nextgen/global/products/informatics-and-software/waters_connect-for-quantitation.html>

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