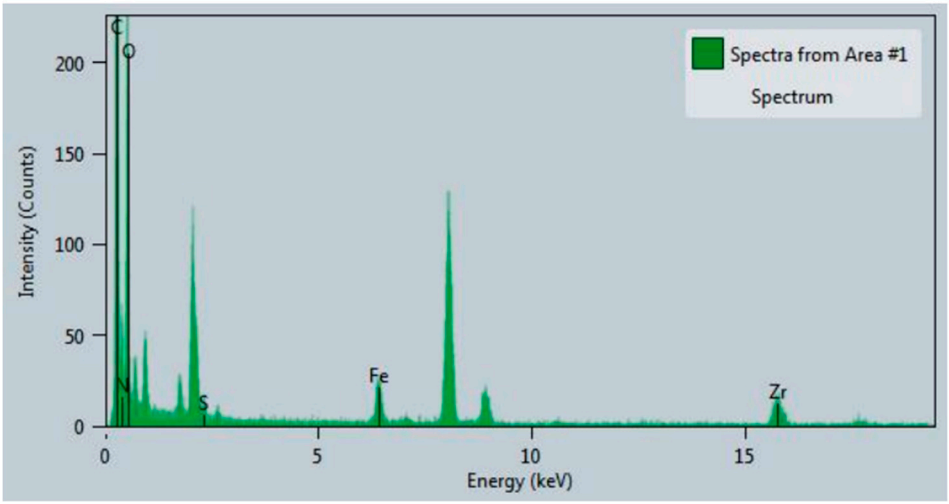



**Figure S1** Scanning element content intensity map

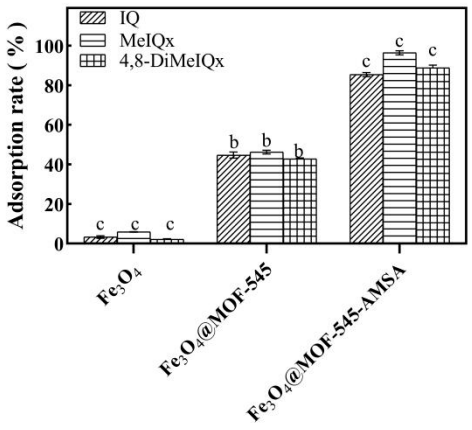



**Figure S2.** Adsorption of heterocyclic aromatic amines with three different adsorbents.Different small letters indicate significant difference ($p$<0.05).

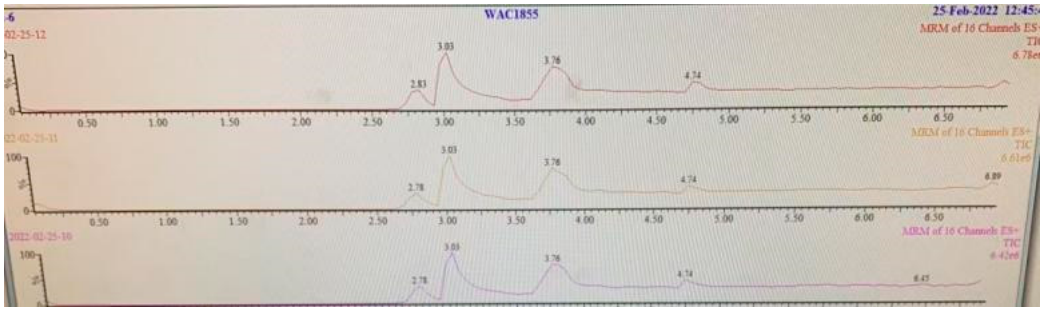



**Figure S3** Multiple reaction monitoring (MRM) chromatograms of three types of HAAs.

**Table S1** HAAs adsorption capacities of $Fe_3O_4$@MOF-545-AMSA.

| nanomaterials | HAAs | Adsorbent amount (mg) | Equilibr-ium time (min) | Desorpti-on time | Recovery (%) | Ref |
|---|---|---|---|---|---|---|
| $AG^{D\text{-}UiO\text{-}66}$ | 12HAAs | 10 | 30 | 10 | 94.65-107.56 | [1] |
| $Fe_3O_4$@COF@Cys | 5HAAs | 10 | 30 | 30 | 90.4-102.8 | [2] |
| $Fe_3O_4$@COF-COOH | 16HAAs | 4 | 20 | 9 | 62.12-126.86 | [3] |
| $Fe_3O_4$@COP | 6HAAs | 10 | 5 | 20 | 82.0 – 109.5 | [4] |
| $Fe_3O_4$@MOF-545-AMS-A | 3HAAs | 3 | 10 | 5 | 83.7–111.0 | This study |

**Table S2.** Chemical name, abbreviated name, and structure of the three selected heterocyclic aromatic amines (HAAs).

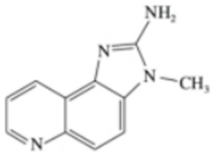
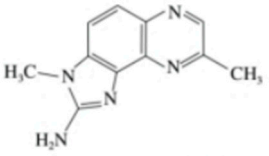
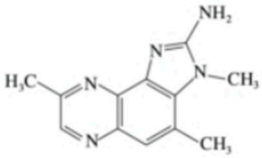
| Chemical name | Abbreviated name | Structure |
|---|---|---|
| 2-amino-3-methylimidazole [4,5-f]quinoline | IQ |  |
| 2-amino-3,8-dimethylimidazo[4,5-f]quinoline | MeIQx |  |
| 2-amino-3,4,8-dimethylimidazole-[4,5-f]-quinoxaline | 4,8-DiMelQx |  |

**Table S3** The LOD and LOQ of heterocyclic aromatic amines in four different meat products (μg/kg), n=3.

| Sample name | IQ | | MeIQx | | 4,8-DiMeIQx | |
|---|---|---|---|---|---|---|
| | LOD | LOQ | LOD | LOQ | LOD | LOQ |
| Dezhou braised chicken | 0.2 | 0.5 | 0.5 | 1.0 | 0.1 | 0.5 |
| Spiced beef | 0.1 | 0.5 | 0.3 | 1.0 | 0.5 | 1.0 |
| Fried pork | 0.2 | 0.5 | 0.1 | 0.3 | 0.5 | 1.0 |
| Crispy yellow croaker | 0.2 | 0.5 | 0.1 | 0.5 | 0.1 | 0.3 |

**Table S4** Automated verification of the recovery rate and relative standard deviation of heterocyclic aromatic amines (HAAs) standards, (n=3).

| HAAs | Recovery (%) | Mean value (%) | RSD (%) |
|---|---|---|---|
| IQ | 75.2 | 79.5 | 1.02 |
| | 82.5 | | |
| | 82.1 | | |
| | 78.5 | | |
| | 75.9 | | |
| | 79.0 | | |
| | 82.2 | | |
| | 80.9 | | |
| | 79.9 | | |
| MeIQx | 87.8 | 79.8 | 1.53 |
| | 75.6 | | |
| | 80.0 | | |
| | 75.2 | | |
| | 76.9 | | |
| | 84.2 | | |
| | 78.7 | | |
| 4,8-DiMeIQx | 82.1 | 80.5 | 1.18 |
| | 78.7 | | |
| | 81.5 | | |
| | 80.0 | | |
| | 77.6 | | |
| | 82.8 | | |
| | 75.4 | | |
| | 86.1 | | |

**Table S5** Automated extraction instrument for detecting the content and relative standard deviation of heterocyclic aromatic amines (HAAs) in four different meat products (n=8).

| Sample | HAAs | Content (ng/g) | Mean value (ng/g) | RSD (%) |
|---|---|---|---|---|
| Dezhou braised chicken | IQ | 1.164 | 1.142 | 3.84 |
| | | 1.165 | | |
| | | 1.095 | | |
| | | 1.022 | | |
| | | 0.968 | | |
| | | 1.191 | | |
| | | 1.291 | | |
| | | 1.242 | | |
| | MeIQx | N.D. | N.D. | N.D. |
| | 4,8-DiMeIQx | N.D. | N.D. | N.D. |
| Spiced beef | IQ | 1.420 | 1.463 | 4.46 |
| | | 1.478 | | |
| | | 1.492 | | |
| | | 1.620 | | |
| | | 1.632 | | |
| | | 1.335 | | |
| | | 1.464 | | |
| | | 1.265 | | |
| | MeIQx | N.D. | N.D. | N.D. |
| | 4,8-DiMeIQx | N.D. | N.D. | N.D. |
| Fried pork | IQ | 1.643 | 1.591 | 3.7 |
| | | 1.509 | | |
| | | 1.620 | | |
| | | 1.755 | | |
| | | 1.630 | | |
| | | 1.401 | | |
| | | 1.554 | | |
| | | 1.615 | | |
| | MeIQx | 0.550 | 0.551 | 2.35 |
| | | 0.556 | | |
| | | 0.553 | | |
| | | 0.572 | | |
| | | 0.651 | | |
| | | 0.610 | | |
| | | 0.457 | | |
| | | 0.462 | | |

| | | | | |
|---|---|---|---|---|
| | 4,8-DiMeIQx | N.D. | N.D. | N.D. |
| Crispy yellow croaker | IQ | 2.546 | 2.448 | 4.28 |
| | | 2.384 | | |
| | | 2.488 | | |
| | | 2.509 | | |
| | | 2.267 | | |
| | | 2.285 | | |
| | | 2.516 | | |
| | | 2.588 | | |
| | MeIQx | N.D. | N.D. | N.D. |
| | 4,8-DiMeIQx | 0.479 | 0.482 | 1.55 |
| | | 0.468 | | |
| | | 0.500 | | |
| | | 0.546 | | |
| | | 0.437 | | |
| | | 0.411 | | |
| | | 0.524 | | |
| | | 0.490 | | |

N.D.:Not detected

**Table S6** The table of high-throughput automated extraction program.

| Step | Name | Plate | Mixing time (s) | Volume (μL) | Magnetic attraction time (s) | Waiting time (min) | Mixing speed |
|---|---|---|---|---|---|---|---|
| 1 | take magnetic beads | 1 | 5 | 500 | 60 | 0 | slow |
| 2 | adsorption | 2 | 600 | 1000 | 60 | 0 | slow |
| 3 | desorption | 4 | 300 | 1000 | 60 | 0 | slow |
| 4 | discard | 5 | 0 | 500 | 0 | 0 | slow |

**Table S7** Overview of the gradient condition parameters (a) and ESI-MS condition parameters (b)

**(a)** The gradient condition parameters of UPLC-MS/MS analysis

| **Program of Gradient Elution** | | |
|---|---|---|
| **Time (min)** | **Mobile phase A (%)** | **Mobile phase B (%)** |
| 0 | 95.0 | 5.0 |
| 0.5 | 95.0 | 5.0 |
| 3.0 | 70.0 | 30.0 |
| 6.0 | 40.0 | 60.0 |
| 6.1 | 5.0 | 95.0 |
| 6.5 | 5.0 | 95.0 |
| 6.6 | 95.0 | 5.0 |
| 7.0 | 95.0 | 5.0 |

(b) The ESI-MS condition parameters of UPLC-MS/MS analysis

| **Basic parameters of mass spectrometer** | |
|---|---|
| Ion mode | ESI, negative |
| Gas temperature | 350 ℃ |
| Scan type | multiple reaction monitoring (MRM) |

| **MRM parameter table** | | | | |
|---|---|---|---|---|
| **RM** | **Precursor ion (m/z)** | **Product ion (m/z)** | **The cone hole voltage (V)** | **Collision voltage(CE)** |
| IQ | 199.1 | 184.0[a] | 40 | 35 |
| | | 157.0 | 40 | 35 |
| MelQx | 213.9 | 130.9[a] | 40 | 35 |
| | | 199.0 | 40 | 35 |
| 4,8-DiMelQx | 227.9 | 159.8[a] | 40 | 35 |
| | | 212.1 | 40 | 35 |

[a] represents quantitative ion

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[1] Zhao, Q.; Hou, M.H.; Zhang, L.G.; et al. Defective UiO-66/Cellulose Nanocomposite Aerogel for the Adsorption of Heterocyclic Aromatic Amines. Food Chemistry. **2024**, 449, 139225.

[2] Fan, Y.M.; Shi, Y.H.; He, R.; et al. Simultaneous Detection of Heterocyclic Aromatic Amines and Acrylamide in Thermally Processed Foods by Magnetic Solid-Phase Extraction Combined with HPLC-MS/MS Based on Cysteine-Functionalized Covalent Organic Frameworks. Food Chemistry. **2023**, 424, 136349.

[3] Wang, T.; Liu, W.; Chen, L.; et al. A Magnetic Carboxyl-Functionalized Covalent Organic Framework for the Efficient Enrichment of Foodborne Heterocyclic Aromatic Amines prior to UPLC-MS Analysis. Food Chemistry. **2024**, 461, 140852.

[4] Feng, Y.,Xu, Y.; Li, W.; Chen, S.; Su, Z.; Xi, L.; Li, G. Improved enrichment and analysis of heterocyclic aromatic amines in thermally processed Foods by magnetic solid phase extraction combined with HPLC-MS/MS. Food Control. **2022**, 137, 108929.