Supplementary Information (SI) for Environmental Science: Processes & Impacts.

Supplementary Information

Fingerprinting the emissions of volatile organic compounds emitted from the cooking of oils, herbs, and spices.

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Qualitative measurement of VOCs in the cooking plume of herbs and spices (cooking #2a experiments)

The samples collected in cooking #2a experiments, were analysed qualitatively using a gas chromatograph coupled to a time-of-flight mass spectrometer and a flame ionisation detector. At first, the moisture in the sample air was removed by passing it through a cold glass finger (-30 °C) and, then 500 mL of this dried air was pre-concentrated for 20 min at 25 mL min^{-1} on an ozone precursor dual-bed sorbent cold trap (Markes International, UK) held at -30 °C. Following the preconcentration, the trap was heated at 200 °C for 3 min and the desorbed sample was injected into the GC system (Agilent 7890A) in a splitless mode using nitrogen as a carrier gas. The GC oven housed two columns: column 1 (CP9223 VF-WAXms, Agilent; 60 m×250 µm×0.5 µm, operating at 1.5 Ml min^{-1}) coupled to the TOF-MS detector, and column 2 (CP7565 CP-Al_2O_3/ Na_2SO_4, Agilent; 50 m×320 µm×5 µm, operating at 3 mL min^{-1}) coupled to the FID detector. The GC oven temperature was programmed to start at 40 °C (3 min hold), then ramped to 80 °C at 2.5 °C min^{-1}, and further ramped to 250 °C at 10 °C min^{-1}. The peak identification for MS and FID was performed using the NIST 2011 mass spectral library and a 30-component NPL gas standard mixture. The compounds that were not present in the calibration mixture were instead semi-quantified using the effective carbon number (ECN) methodology (Faiola *et al.*, 2012; Scanlon and Willis, 1985; Sternberg, 1962). Using this approach, a relative response factor (RRF) was determined (equation S1):

$$RRF = \frac{MW_x \times ECN_{ref}}{MW_{ref} \times ECN_x} \tag{S1}$$

Where, MW_x and MW_{ref} are the molar masses of the analyte compound x and reference compound respectively, and ECN_x and ECN_{ref} are effective carbon numbers of analyte compound x and reference compounds respectively (Faiola *et al.*, 2012; Sternberg, 1962).

The reference compounds were chosen from the calibration mixture based on the similarities in carbon number and molecular structure. Where a suitable reference compound was not present (Carbon number = 1 or > 9), the GC-FID response was extrapolated, and an appropriate straight-chain aliphatic hydrocarbon not in the mixture was used instead. The resulting calculated RRF values are shown in Table S6. The ECN contribution of sulphur has not been determined in the literature, and so here was assumed to be zero. The RRF values were multiplied by the measured raw GC-FID peak areas, giving a new set of corrected peak area values. Additionally, for the reference compounds that were not present in the calibration mixture, the calibration factors were approximated through a linear gradient of calibration factors with respect to the carbon number (see Figure S2).

Quantification of monoterpenes by GC-MS in cooking #2 experiments

The offline samples collected during the cooking #2 experiments were analysed using GC-MS for speciating the monoterpenes. Five separate monoterpenes were identified: d-limonene, α-pinene, camphene, 3-carene, and β-pinene (see Table S7). The identification and quantification of these compounds was carried out using the calibration standard #3. Although camphene could not be directly quantified using the gas standard, its levels were estimated by assuming that all monoterpenes had a similar total ion signal-to-concentration ratio. At first, a relative response factor was calculated by dividing the sum of mixing ratios for all four quantified monoterpenes with the sum of the total ion peak areas and then the resulting factor was multiplied by the camphene total ion peak area to arrive at an estimated mixing ratio. This resulted in camphene mixing ratios of 88 ppbv for ginger, 1.5 ppbv for cumin 1, and 0.19 ppbv for cumin 2. However, it should be noted that these estimates are semi-quantitative due to the nature of the assumption. Owing to significant differences in the mixing ratios measured by the two instruments (SIFT-MS (8 ppb) and GC-MS (1.1 ppb)) for garlic (see Figure S5), it was suspected that there was substantial interference on the m/z 136 ion on NO+ channel in SIFT-MS during the garlic cooking plume. Since the exact interfering compound(s) could not be identified, the SIFT-MS total monoterpenes values for garlic were discarded and instead assumed to be equal to the value observed for chilli as the sum of the GC-MS monoterpene mixing ratios was same for both spices. No similar interference was observed for any other spice within the instrumental measurement uncertainty (Figure S5).

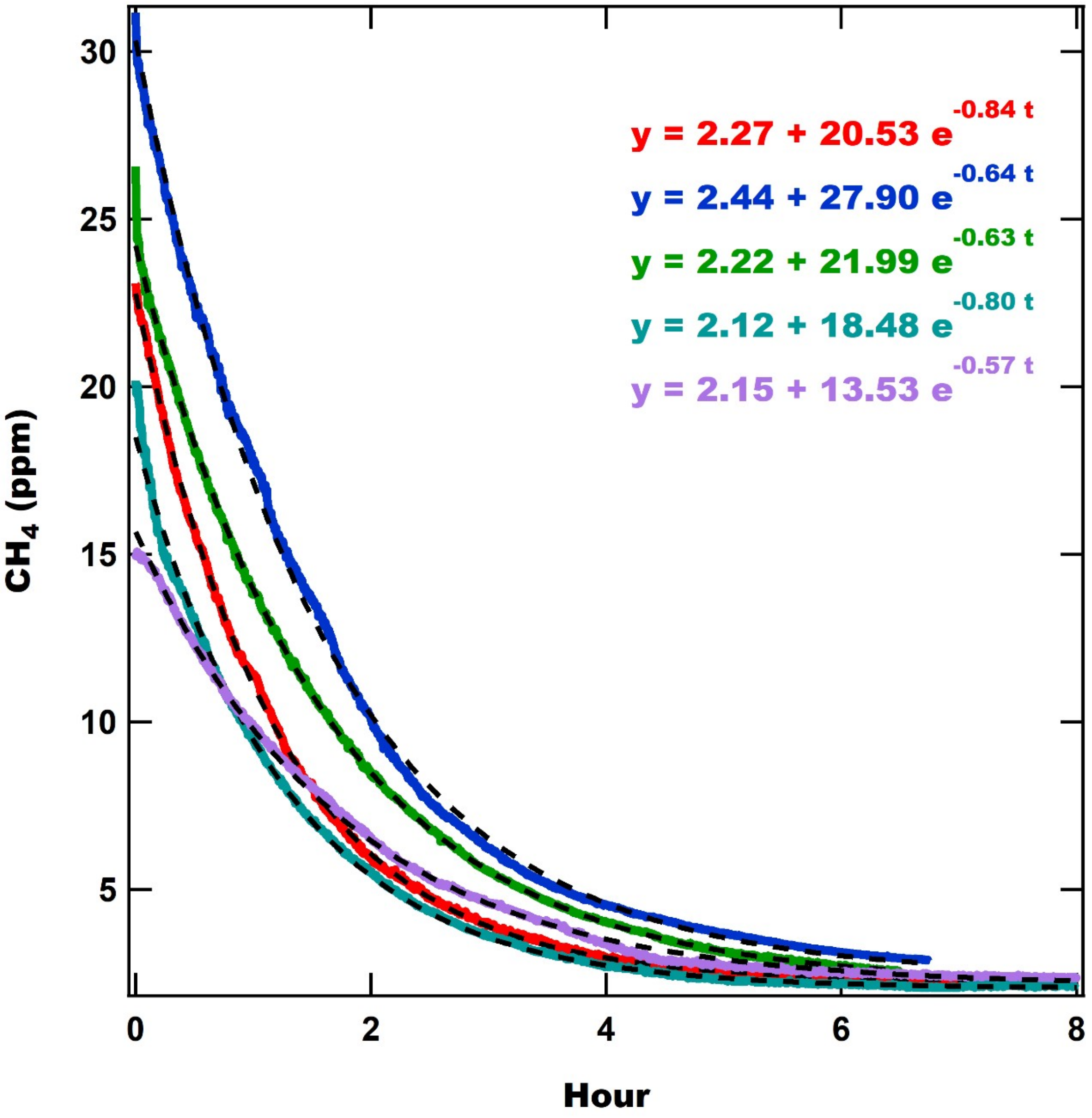

Figure S1. Decay of the CH_4 concentrations during the air change rate (ACR) for the experimental site (fume cupboard switched off and door closed).

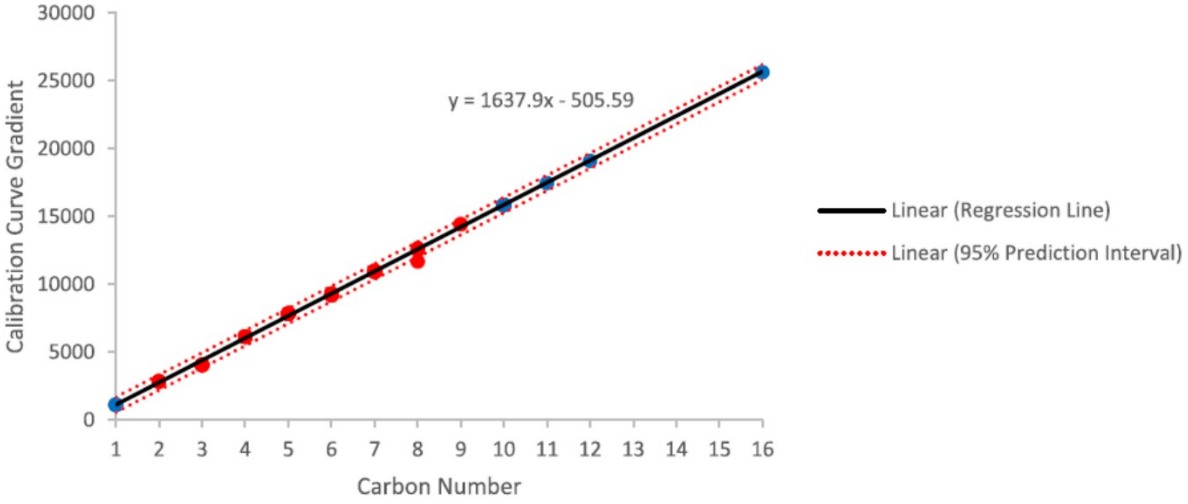

Figure S2. Plot used for determining the GC-FID calibration factors for the compounds that were not present in the calibration mixture. Red points represent the experimentally calculated calibration factors while blue points represent the factors determined from the linear regression ($r^2 = 0.996$). 95% of data points were within the 95% confidence interval of the linear regression fit.

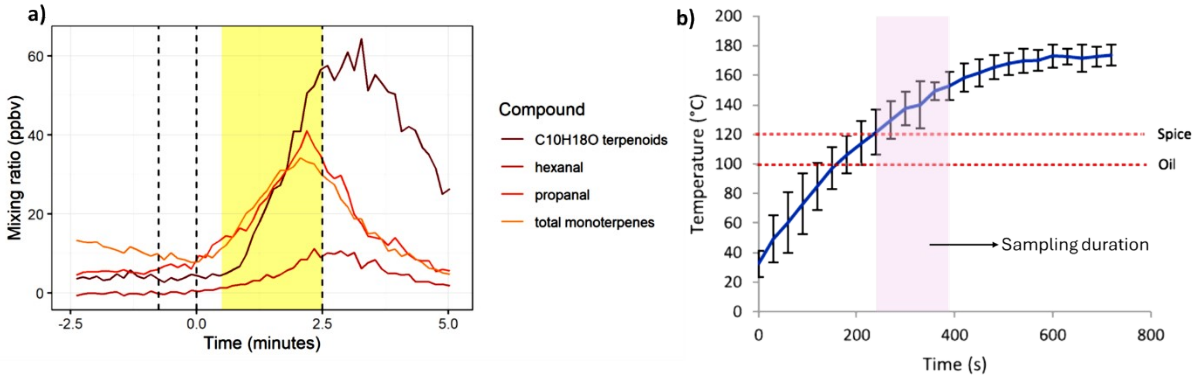

Figure S3. (a) An example of SIFT-MS results (fresh ginger cooking) for four compounds in the SIM: monoterpenes, propanal, hexanal, and eucalyptol. Dashed lines indicate oil addition, spice addition, and cooking end respectively. The shaded area is the duration of sampling for GC-MS; (b) The temperature profile of the cooking #2 experiments. The error bars show the standard deviation of the data points derived over 10 different repeat experiments. The dashed lines show the temperature at which the oil and spice were added to the pan. The shaded region shows the duration of offline sampling.

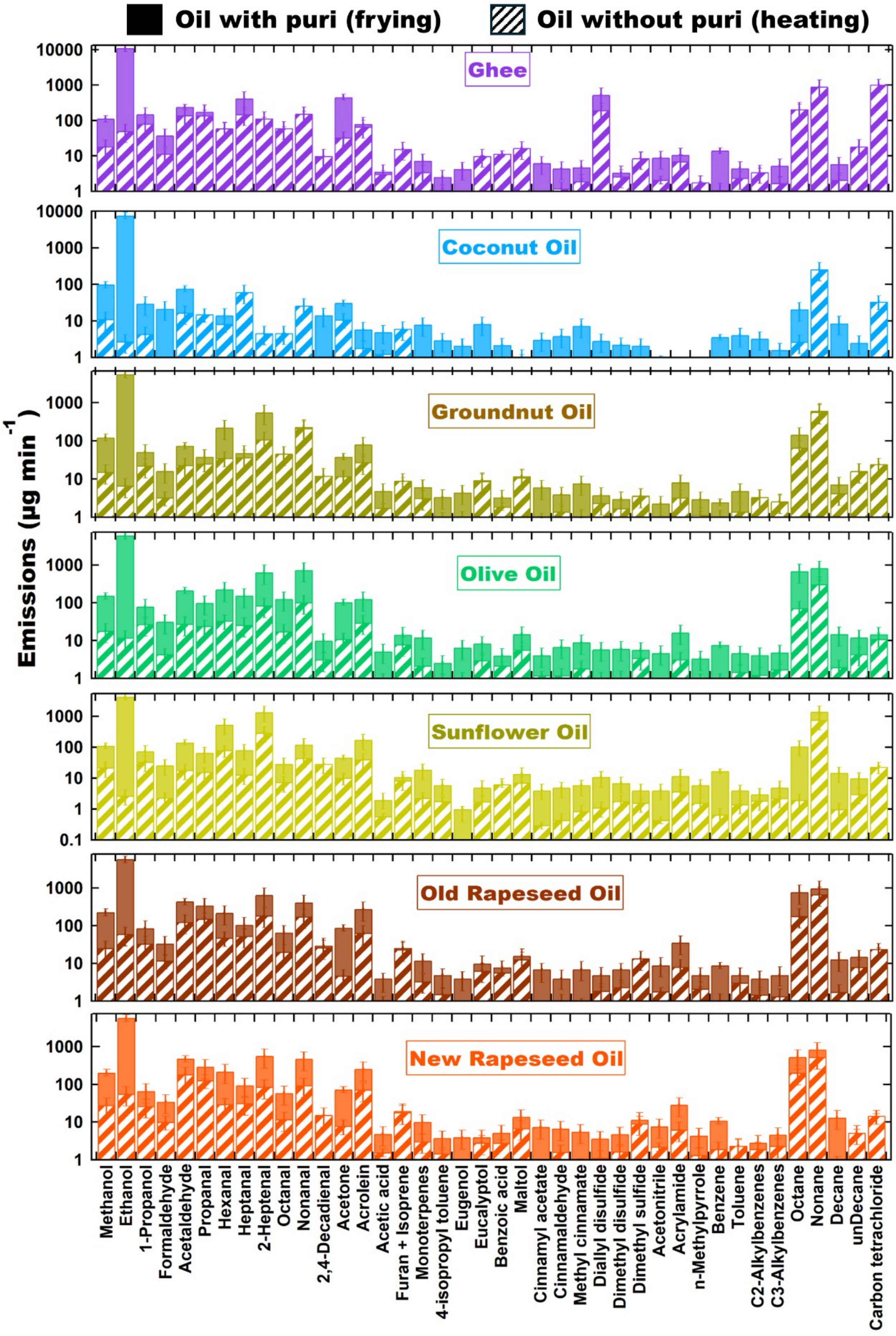

Figure S4. Comparison of the emission profiles (µg/min) of the VOC were measured during the frying of puris in different oils and isolated heating of the oils. Error bars represent the total uncertainty in the calculated emissions.

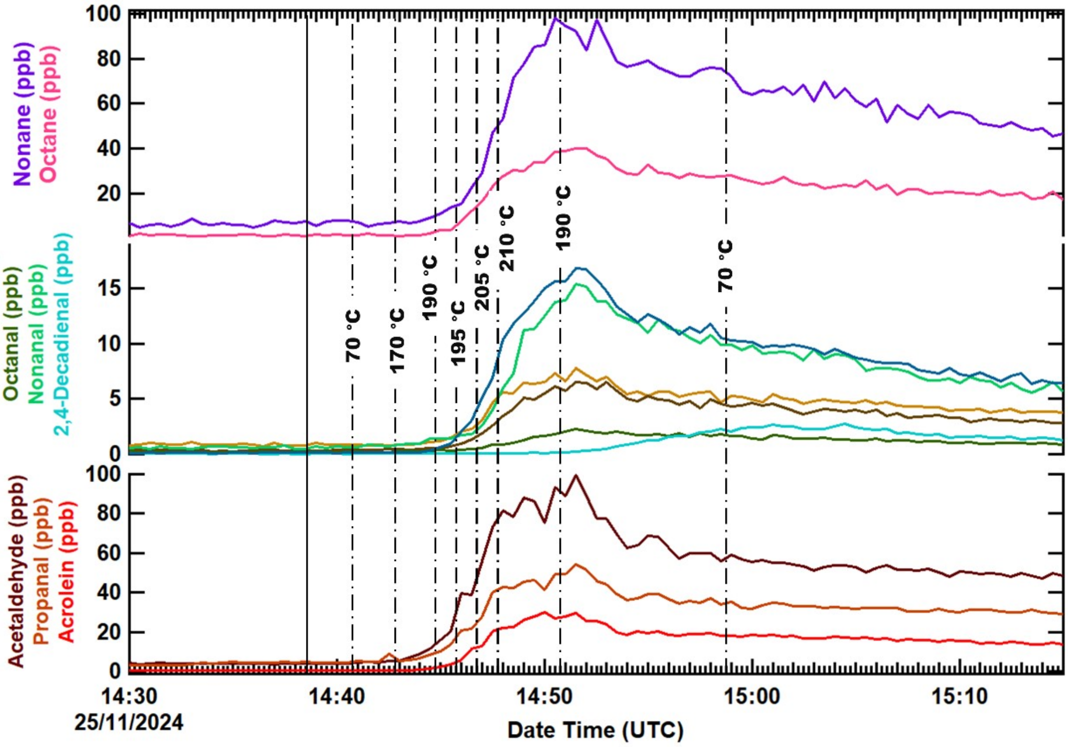

Figure S5. Real-time mixing ratios of selected VOCs measured during the heating of the rapeseed oil following the protocol described in section 2.2.1. Also shown are the snapshot temperatures recorded for the oil (in the middle of the pan).

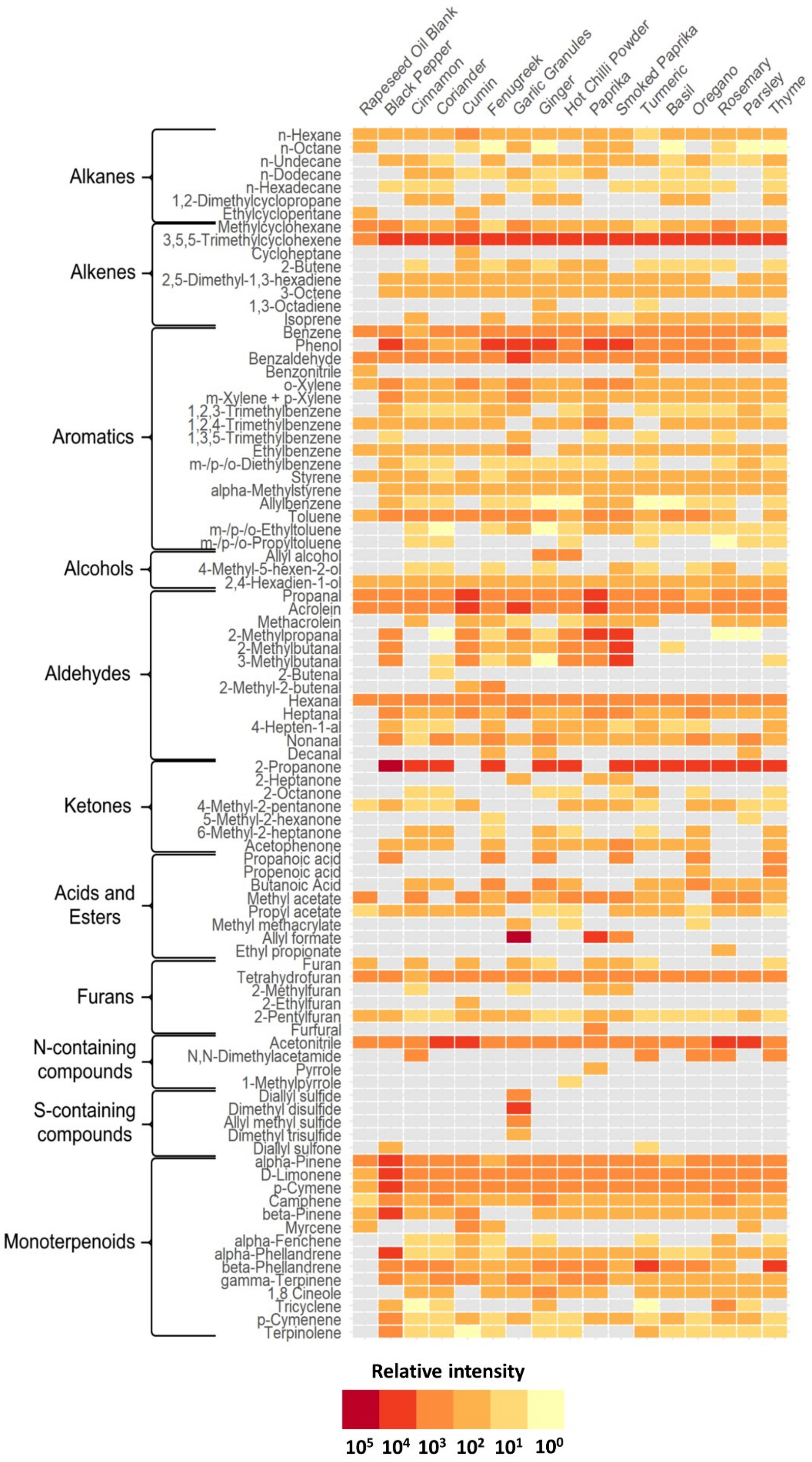

Figure S6. Visualisation of VOC emissions observed when sampling from the cooking plume of five dried herbs and eleven ground spices (cooking 2a experiments). VOCs were identified by GC-ToF-MS and relative intensities estimated from GC-FID response using the equivalent carbon number (ECN) approach.

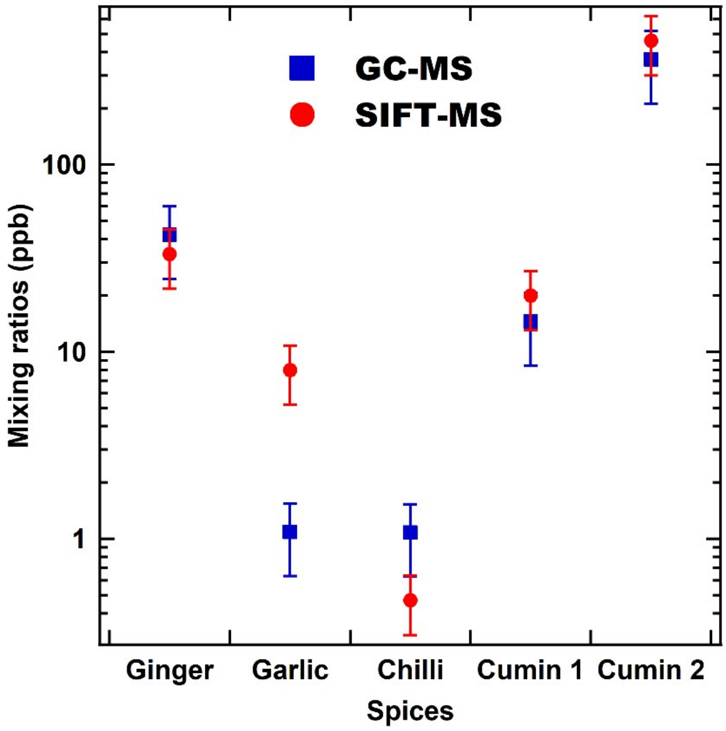

Figure S7. Total monoterpenes measured by SIFT-MS and GC-MS during the cooking of different spices. Error bars represent the measurement uncertainty of respective instruments. The total monoterpene measurement of GC-MS shown here (in blue marker) is a sum of d-limonene, α-pinene, camphene, 3-carene, and β-pinene that were individually quantified by GC-MS.

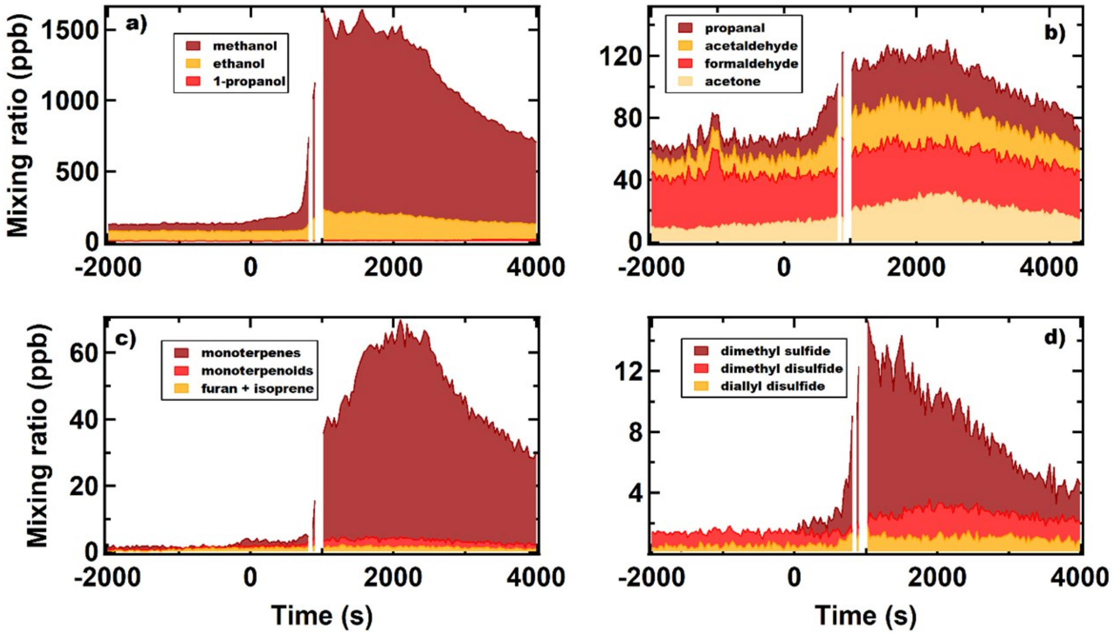

Figure S8. Real time mixing ratios for **(a)** alcohols, **(b)** aldehydes and ketones, **(c)** terpenes, and **(d)** S-containing compounds measured by SIFT-MS during the cooking chicken curry. The stacked shaded areas indicate the contribution of each species to the total for that plot.

The gap in the data at 900-1000 s was because of the technical issues with the instrument failing to record the data.

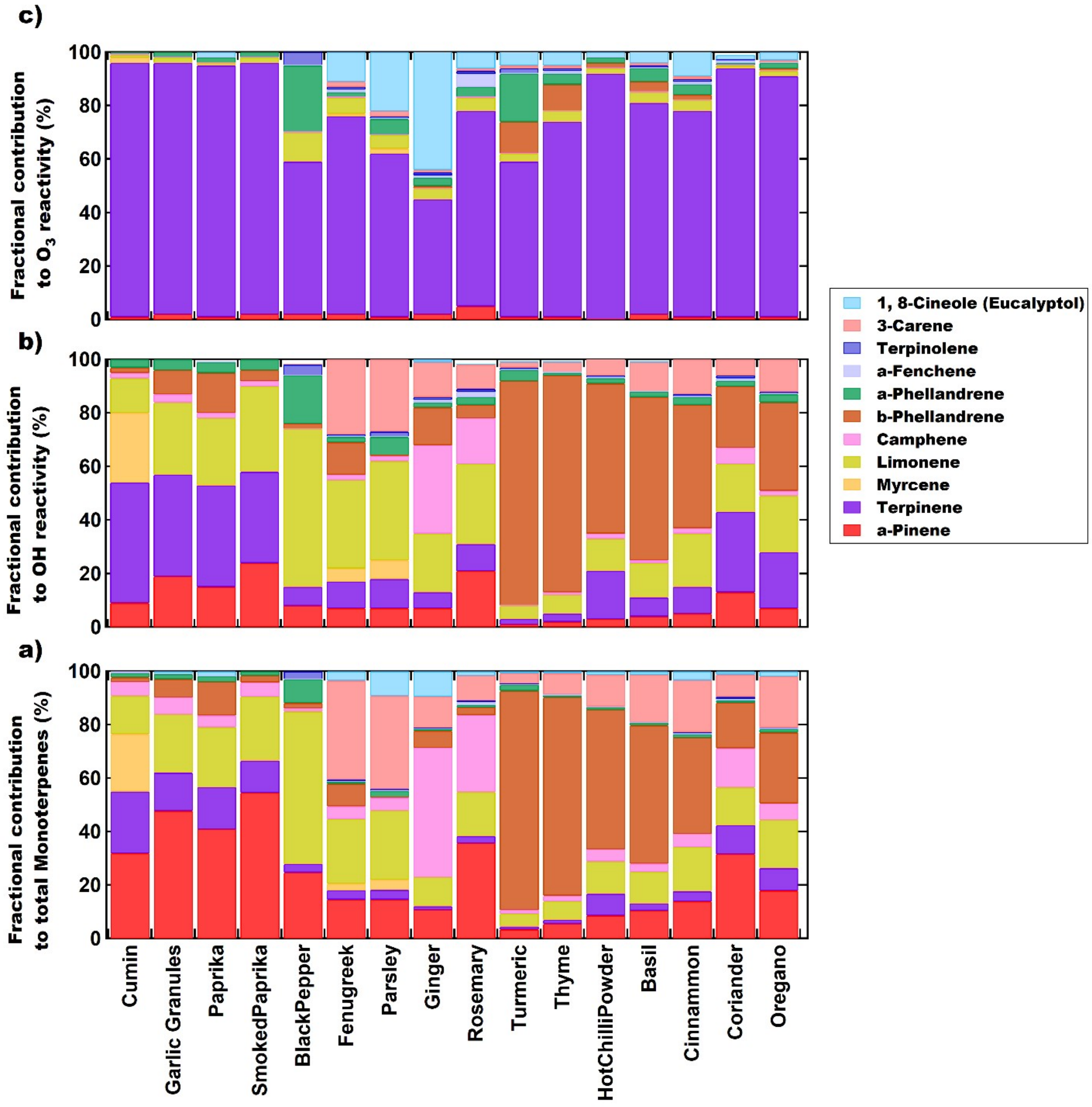

Figure S9. (a) The relative abundance (%) of monoterpenes identified in the cooking plume of spices and herbs, (b) the relative abundance (%) of monoterpenes scaled to their respective OH rate coefficients, and (c) the relative abundance (%) of monoterpenes scaled to their respective O_3 rate coefficients.

Table S1. Details of cooking 1 experiment of frying puris in different oils

Oil	**Volume used (mL)**	**Temperature at which 1st puri fried (°C)**	**Temperature at the end of frying 2nd puri (°C)**	**Total time of experiment (min)**
Rapeseed oil (new)	100	170	190	20
Rapeseed oil (old)	100	170	200	23
Sunflower oil	100	170	190	20
Olive oil	100	170	200	21
Groundnut oil	100	170	195	23
Coconut oil	100	170	190	24
Ghee	100	170	200	25

Table S2. Details of herbs and spices included in investigations, indicating which experiments each herb or spice was included in each.

*A= Plume speciation during Cooking experiments 2a; B = Quantification of emission rates during Cooking experiments 2; C = Cooking experiment 3 (Cooking of Chicken curry)

Herb/spice	**Type**	**Quantity**	**Mass (g)**	**Usage***
Cumin	Ground spice	1 tsp	2.4	A, B, C
Garlic	Granules	1 tsp	3.2	A
Paprika	Ground spice	1 tsp	2.3	A
Smoked paprika	Ground spice	1 tsp	2.6	A
Black pepper	Ground spice	1 tsp	3.1	A
Parsley	Dried herb	1 tsp	0.5	A
Fenugreek	Ground spice	1 tsp	3.1	A
Ginger	Ground spice	1 tsp	2.2	A
Rosemary	Dried herb	1 tsp	1.5	A
Turmeric	Ground spice	1 tsp	2.2	A, C
Thyme	Dried herb	1 tsp	1.0	A
Hot chilli powder	Ground spice	1 tsp	1.9	A, C
Basil	Dried herb	1 tsp	1.1	A
Cinnamon	Ground spice	1 tsp	1.6	A
Coriander	Ground spice	1 tsp	1.7	A, C
Oregano	Dried herb	1 tsp	0.7	A
Ginger	Fresh spice		10	B, C
Chilli pepper	Fresh spice		10	B, C
Garlic	Fresh spice		10	B, C

Table S3. Details of the ingredients used in the full recipe cooking of chicken curry (cooking experiment 3).

Ingredient	Quantity	Mass (g)	Preparation
Rapeseed oil	2 tbsp (10 mL)	30	
White onion		111	Peeled and diced
Fresh Garlic		5	Peeled and finely chopped
Fresh Ginger		6	Peeled and finely chopped
Fresh Chilli pepper		5	Peeled and finely chopped
Ground cumin	1 tsp	5.5	
Ground coriander	1 tsp	5.5	
Chilli powder	0.25 tsp	1.5	
Turmeric	0.25 tsp	1.5	
Garam Masala	0.25 tsp	1.5	
Cooking salt	0.25 tsp	1.5	
Chicken breast		308	Diced
Tinned chopped tomatoes		130	
Water	250 mL	250	

Table S4. List of compounds measured using SIFT-MS, their respective protonated m/z ratios, respective reagent (H_3O^+, NO^+, O_2^+), product ions, and overall measurement uncertainty. VOC assignments have been made following their occurrence in food materials and cooking processes as reported in the literature. *indicates the VOCs with potential interferences from other isobaric compounds and mass fragments. Corrections have been applied to these masses for any interferences mentioned in the column. For example, acetone was corrected by subtracting the limonene (25% contribution with NO^+ primary ion) and *n*-Octane (5% contribution with NO^+ primary ion) interferences at m/z88, and propanal was corrected by subtracting the corrected acetone mixing ratios from m/z59 (with H3O$^+$ primary ion) mixing ratios. The calibrated compounds are highlighted in bold.

m/z	Compound	Potential interferences	Reagent ion	Product ion	References	Overall measurement uncertainty (%)
31	Formaldehyde	---	H_3O^+	CH_3O^+	Arata et al., 2021; Ho et al., 2006; Peng et al., 2017	35
33	**Methanol**	---	H_3O^+	CH_5O^+	Arata et al., 2021	8
42	**Acetonitrile***	Undecane (8%)	H_3O^+	$CH_3CN.H^+$	Arata et al., 2021	6
45	**Acetaldehyde**	---	H_3O^+	$C_2H_4O.H^+$	Arata et al., 2021; Ho et	

					al., 2006; Peng et al., 2017; Klein et al, 2016a	
47	**Ethanol**	---	H_3O^+	$C_2H_7O^+$	Arata et al., 2021	8
59	Propanal*	Acetone (100%)	H_3O^+	$C_3H_7O^+$	Arata et al., 2021; Ho et al., 2006; Peng et al., 2017; Klein et al, 2016a	35
72	Acrylamide		H_3O^+	$C_2H_3NH_2CO.H^+$	Perera et al., 2021; Ditto et al., 2022	35
82	n-Methylpyrrole		H_3O^+	$C_5H_7N.H^+$	Liu et al., 2017	35
101	Hexanal*	C6 ketones	H_3O^+	$C_6H_{13}O^+$	Arata et al., 2021; Peng et al., 2017; Ho et al., 2006; Klein et al, 2016a	35
115	Heptanal*	C7 ketones	H_3O^+	$C_7H_{15}O^+$	Arata et al., 2021; Peng et al., 2017; Klein et al, 2016a	35
123	Benzoic acid	---	H_3O^+	$C_7H_6O_2.H^+$	Del Olmo et al., 2017; Benfenati et al., 1998	35
129	Octanal*	C8 ketones,	H_3O^+	$C_8H_{17}O^+$	Ho et al., 2006; Peng et al., 2017; Klein et al, 2016a	35
143	Nonanal*	C9 ketones	H_3O^+	$C_9H_{19}O^+$	Ho et al., 2006; Peng et al., 2017; Klein et al, 2016a	35
161	Decane	---	H_3O^+	$C_{10}H_{22}.H_3O+$	Cheng et al., 2016	35
163	Methyl cinnamate	---	H_3O^+	$C_{10}H_{10}O_2.H^+$	Wang et al., 2021; Huang et al., 2022	35
205	Sesquiterpenes	---	H_3O^+	$C_{15}H_{25}^+$	Klein et al, 2016b; Arata et al., 2021	35
59	1-Propanol	---	NO^+	$C_3H_7O^+$		35
68	Furan + **Isoprene**	---	NO^+	$C_4H_4O^+$	Arata et al., 2021	6
78	**Benzene**	---	NO^+	$C_6H_6^+$	Arata et al.,	

					2021; Yi et al., 2019; Cheng et al., 2016	
86	Acrolein	---	NO^+	$C_3H_4O.NO^+$	Arata et al., 2021; Ho et al., 2006; Peng et al., 2017; Klein et al, 2016a	35
88	**Acetone***	Monoterpenes (25%), *n*-Octane (5%)	NO^+	$C_3H_6O.NO^+$	Arata et al., 2021	6
90	Acetic acid	---	NO^+	$CH_3COOH.NO^+$	Arata et al., 2021; Zhang et al., 2019	35
92	**Toluene**	Monoterpenes (3%)	NO^+	$C_7H_8^+$	Arata et al., 2021; Cheng et al., 2016	6
106	C2-Alkylbenzenes	---	NO^+	$C_8H_{10}^+$	Arata et al., 2021; Cheng et al., 2016	35
108	Dimethyl disulfide	---	NO^+	$(CH_3)_2S_2^+$	Arata et al., 2021; Kabir and Kim, 2011	35
111	2-Heptenal	---	NO^+	$C_7H_{11}O^+$	Peng et al., 2017; Klein et al, 2016a	35
120	C3-Alkylbenzenes	---	NO^+	$C_9H_{12}^+$	Arata et al., 2021; Cheng et al., 2016	35
120	Diallyl disulfide	---	NO^+	$(C_3H_5)_2S_2^+$	Liu et al., 2017; Sato et al., 2020	35
134	4-Isopropyl toluene	---	NO^+	$C_{10}H_{14}^+$	Klein et al, 2016b	35
136	**Monoterpenes**	---	NO^+	$C_{10}H_{16}^+$	Arata et al., 2021; Klein et al, 2016b	6
151	2,4-Decadienal	---	NO^+	$C_{10}H_{15}O^+$	Peng et al., 2017; Klein et al, 2016a	35
154	Eucalyptol*	Other monoterpenoids	NO^+	$C_{10}H_{18}O^+$	Liu et al., 2017	35
164	Eugenol	---	NO^+	$C_{10}H_{12}O_2^+$	Koeduka et al., 2006	35
176	Cinnamyl acetate	---	NO^+	$C_{11}H_{12}O_2^+$	Lee et al., 2018	35
76	Dimethyl sulfide	---	O_2^+	$(CH_3)_2S^+$	Kabir and Kim, 2011	35
85	Octane	Sesquiterpenes (37%), Undecane (31%), Nonane	O_2^+	$C_6H_{13}^+$	Cheng et al., 2016	35

		(20%), Octanal (10%), Nonanal (6%)				
99	Nonane	Undecane (6%)	O_2^+	$C_7H_{15}^+$	Cheng et al., 2016	35
117	Carbon tetrachloride	4-Isopropyl toluene (90%)	O_2^+	$C(Cl\text{-}35)_3^+$	Zhang et al., 2023	35
126	Maltol	Undecane (2%)	O_2^+	$C_6H_6O_3^+$	Zhang et al., 2012	35
132	Cinnamaldehyde	---	O_2^+	$C_9H_8O^+$	Lee et al., 2018	35
156	Undecane	---	O_2^+	$C_{11}H_{24}^+$	Cheng et al., 2016	35

Table S5. Details of the calibration mixtures used for calibrating SIFT-MS and GC-MS.

Compounds	**Calibration standard 1**		**Calibration standard 2**		**Calibration standard 3**	
	Mixing ratio (ppm)	**Uncertainty (%)**	**Mixing ratio (ppm)**	**Uncertainty (%)**	**Mixing ratio (ppb)**	**Uncertainty (%)**
Acetaldehyde	6.00	5	0.966	5		
Acetone	10.54	5	0.995	5		
Acetonitrile	1.92	5				
Benzene			0.993	5		
3-Carene					5.27	5
1,8-Cineole (Eucalyptol)					4.53	5
Ethanol	49.20	5	0.956	5		
Isoprene	12.43	5				
Limonene	2.28	6			5.02	5
Methanol	77.6	5	0.990	5		
α-Pinene					5.04	5
β-Pinene					4.75	5
Toluene	4.00	5				

Table S6. Parameters used for the semi-quantitative calculations of VOCs measured using GC-ToF-FID via relative response factors and ECN.

Compound	**Carbon no**	**Reference compound**	**ECN_x**	**ECN_{ref}**	**RRF**
Methylcyclohexane	7	n-Heptane	7	7	0.980
Ethylcyclohexane	7	n-Heptane	7	7	0.980
n-Hexane	6	n-Hexane	6	6	1.000
n-Octane	8	n-Octane	8	8	1.000
Propanal	3	Propane	2	3	1.976
Furan	4	Furan	3	4	1.562
2-Methylpropanal	4	n-Butane	3	4	1.654
2-Propanone	3	Propane	2	3	1.976
Methyl acetate	3	Propane	1.75	3	2.880
Acrolein	3	Propane	1.9	3	2.007
Tetrahydrofuran	4	n-Butane	3	4	1.654
2-Methylfuran	5	n-Pentane	4	5	1.422
Cycloheptane	7	n-Heptane	7	7	0.980
Tetrachloromethane	1	Methane	0.52	1	18.442
Methacrolein	4	n-Butane	2.9	4	1.663
Ethyl acetate	4	n-Butane	2.75	4	2.205
Methanol	1	Methane	0.4	1	4.994
2-Methylbutanal	5	n-Pentane	4	5	1.492
3-Methylbutanal	5	n-Pentane	4	5	1.492
Dichloromethane	1	Methane	0.76	1	6.967
Ethanol	2	Ethane	1.4	2	2.189
Benzene	6	Benzene	6	6	1.000
2-Ethylfuran	6	Benzene	5	6	1.261
4-Methyl-5-hexen-2-ol	7	n-Heptane	6.15	7	1.297
Allyl methyl sulfide	4	n-Butane	3.9	4	1.556
Ethyl propionate	5	n-Pentane	3.75	5	1.887
Propyl acetate	5	n-Pentane	3.75	5	1.887
Pentanal	5	n-Pentane	4	5	1.492
Trichloroethylene	2	Ethane	2.05	2	4.263
1H-Perflurorhexane	6	n-Hexane	6	6	3.714
Tricyclene	10	n-Decane	10	1	0.957
Methyl methacrylate	5	n-Pentane	3.65	5	1.901
4-Methyl-2pentanone	6	n-Hexane	5	6	1.395
Acetonitrile	2	Ethane	1.3	2	2.100
α-Pinene	10	n-Decane	9.9	1	0.967
Trichloromethane	1	Methane	0.64	1	11.629
2-Butene	4	n-Butane	3.9	4	0.990
1-Propanol	3	Propane	2.4	3	1.704
Toluene	7	Toluene	7	7	1.000

2-Butenal	4	n-Butane	2.9	4	1.663
α-Fenchene	10	n-Decane	9.9	1	0.967
Camphene	10	n-Decane	9.9	1	0.967
1,2-Dichloroethane	2	Ethane	2	2	3.291
n-Undecane	11	n-Undecane	11	1	1.000
Dimethyl disulfide	2	Ethane	2	2	4.199
Hexanal	6	n-Hexane	5	6	1.395
2-Methyl-2-butenal	5	n-Pentane	3.9	5	1.495
β-Pinene	10	n-Decane	9.9	10	0.967
Allyl formate	4	n-Butane	2.65	4	2.236
Allyl alcohol	3	Propane	2.3	3	1.718
Ethylbenzene	8	Ethylbenzene	8	8	1.000
m-Xylene + p-Xylene	8	m-Xylene + p-Xylene	8	8	1.000
3-Carene	10	n-Decane	9.9	10	0.967
1-Methylpyrrole	5	n-Pentane	4.75	5	1.183
Myrcene	10	n-Decane	9.7	10	0.987
2-Methyl-1-propene	4	n-Butane	3.9	4	0.990
Diallyl sulfide	6	n-Hexane	5.8	6	1.371
α-Phellandrene	10	n-Decane	9.8	10	0.977
Isoprene	5	n-Pentane	4.8	5	0.983
n-Dodecane	12	n-Dodecane	12	12	1.000
2-Heptanone	7	n-Heptane	6	7	1.329
Heptanal	7	n-Heptane	6	7	1.329
o-Xylene	8	o-Xylene	8	8	1.000
D-Limonene	10	n-Decane	9.8	10	0.977
1,8-Cineole	10	n-Decane	9	10	1.205
β-Phellandrene	10	n-Decane	9.8	10	0.977
Chlorobenzene	6	Benzene	6	6	1.441
2-Pentylfuran	9	1,2,3-Trimethylbenzene	9	9	1.150
m/p/o-Ethyltoluene	9	1,2,3-Trimethylbenzene	9	9	1.000
6-Methyl-2-heptanone	7	n-Heptane	7	7	1.279
γ-Terpinene	10	n-Decane	9.8	10	0.977
1,3,5-Trimethylbenzene	9	1,3,5-Trimethylbenzene	9	9	1.000
1,2-Dimethylcyclopropane	5	n-Pentane	5	5	0.972
Styrene	8	Ethylbenzene	7.9	7	0.869
m/p/o-Diethylbenzene	10	n-Decane	10	10	0.929
p-Cymene	10	n-Decane	10	10	0.943
Terpinolene	10	n-Decane	10	10	0.977
2-Octanone	8	n-Octane	7	8	1.283
1,2,4-Trimethylbenzene	9	1,2,4-Trimethylbenzene	9	9	1.000

m/p/o-Propyltoluene	10	n-Decane	10	10	0.943
2,4-Hexadien-1-ol	6	n-Hexane	3.3	6	2.071
4-Hepten-1-al	7	n-Heptane	5.9	7	1.328
2,5-Dimethyl-1,3-hexadiene	8	n-Octane	7.8	8	0.989
1,2,3-Trimethylbenzene	9	1,2,3-Trimethylbenzene	9	9	1.000
1,3-Octadiene	8	n-Octane	7.8	8	0.989
n-Hexadecane	16	n-Hexadecane	16	16	1.000
Allylbenzene	9	1,2,3-Trimethylbenzene	8.9	9	0.994
5-Methyl-2-hexanone	7	n-Heptane	6	7	1.329
Nonanal	9	1,2,3-Trimethylbenzene	8	9	1.331
Dimethyl trisulfide	2	Ethane	2	2	4.199
p-Cymenene	10	n-Decane	9.9	10	0.938
N,N-Dimethylacetamide	4	n-Butane	2.75	4	2.180
Decanal	10	n-Decane	9	10	1.220
Acetic acid	2	Ethane	0.4	2	9.985
3-Octene	8	n-Octane	7.9	8	0.995
Furfural	5	n-Pentane	3	5	2.219
Phenol	6	Benzene	5.25	6	1.377
Pyrrole	4	n-Butane	3.25	4	1.421
Diallyl sulfone	6	n-Hexane	5.8	6	1.755
Propanoic acid	3	Propane	1.4	3	3.600
Benzaldehyde	7	Toluene	6	7	1.344
3,5,5-Trimethylcyclohexene	9	1,2,3-Trimethylbenzene	8.9	9	1.045
Butanoic acid	4	n-Butane	2.4	4	2.527
Benzonitrile	7	Toluene	8.9	7	0.880
Propenoic acid	3	Propane	1.3	3	3.771
Acetophenone	8	Ethylbenzene	7	8	1.293
α-Methylstyrene	9	1,2,3-Trimethylbenzene	8.9	9	0.994

Table S7. Emission rates of monoterpenes. All individual monoterpene emission rates have errors of 53%.

Compounds	**Emission rates (μg min^{-1})**				
	Ginger	**Garlic**	**Chili**	**Cumin 1**	**Cumin 2**
SIFT-MS total monoterpenes	94	-	1.3	1171	52
α-pinene	9.7	0.35	0.29	288	5.7
β -pinene	1.2	-	-	362	13.6
d-limonene	2.3	0.95	1.01	493	30.1
3-carene	-	-	-	22	1.9
camphene	80.9	-	-	4.7	0.67

Table S8. Rate coefficients for the reactions of monoterpenes (identified in the spice cooking experiments) with OH, NO$_3$, and O$_3$ at 298 K, the yield of OH and formaldehyde (HCHO) formed from the reactions between the monoterpenes and ozone, and the calculated OH production/loss ratio. All rate coefficients, OH yields and HCHO yields are from IUPAC Atmospheric Chemical Kinetic Data Evaluation preferred values where possible.

Compound	**Rate coefficients (molecule^{-1} cm^3 s^{-1})**			**OH Yields (%)**	**HCHO Yields (%)**	**OH production/loss**
	k(OH)	**k(NO$_3$)**	**k(O$_3$)**			
α-Pinene	5.30E-11	6.20E-12	9.40E-17	80	19	1.75
β-Pinene	7.90E-11	2.50E-12	1.60E-16	30	63	0.75
Camphene	5.30E-11	6.60E-13	5.00E-19	18	29	0.00
3-Carene	8.80E-11	9.10E-12	4.90E-17	86	25	0.59
Myrcene	2.15E-10	1.10E-11	4.70E-16	63	51	1.69
α-Phellandrene	3.20E-10	7.30E-11	2.90E-15	32	7	3.57
d-Limonene	1.60E-10	1.20E-11	2.10E-16	66	15	1.07
γ-Terpinene	1.70E-10	2.90E-11	1.60E-16	81		0.94
Terpinolene	2.20E-10	9.70E-11	1.60E-15	70	29	6.26
1,8-Cineole	1.04E-11	1.70E-16				
β-Phellandrene	1.70E-10	7.30E-11	5.20E-17			
α-Fenchene						

Table S9. The rate coefficient for the reaction of VOC$_i$ with OH radicals (k_{OH+VOC_i}) and SOA yields (%) compiled from literature. The SOA yields of precursors were adopted from literature for general conditions (organic aerosol (OA) loading of ~10 µg m^{-3}, High NOx levels >100 ppb, and low NOx levels <10 ppb).

Compound	k_{OH+VOC_i}	SOA Yield (%)	
	($\times 10^{-12}$ cm^3 molecule^{-1} s^{-1})	High Nox	Low Nox
Formaldehyde	8.5 [1]	0.000581 [3]	0.00231 [3]
Methanol	0.9 [1]	0.000249 [3]	0.00099 [3]
Acetonitrile	0.0 [1]	0.00083 [3]	0.0033 [3]
Acetaldehyde	14.9 [1]	0.000498 [3]	0.00198 [3]
Ethanol	3.2 [1]	0.000498 [3]	0.00198 [3]
Propanal	19.9 [1]	0.000415 [3]	0.00165 [3]
Acrylamide	11.2 [2]	0.00083 [3]g	0.0033 [3]g
n-Methylpyrrole	120.0 [1]a	0.00083 [3]	0.0033 [3]
Hexanal	28.5 [1]	0.05 [4]h	0.05 [4]h
Heptanal	29.6 [1]	0.05 [4]i	0.05 [4]i
Benzoic acid	11.0 [1]	0.18 [3]j	0.7128 [3]j
Octanal	31.7 [2]	0.05 [4]i	0.05 [4]i
Nonanal	32.0 [1]	0.05 [4]i	0.05 [4]i
Decane	13.1 [1]	0.0026 [3]	0.0231 [3]
Methyl cinnamate	21.8 [2]	0.166 [3]k	0.66 [3]k
Sesquiterpenes	219.0 [1]b	0.0166 [3]l	0.066 [3]l
1-Propanol	5.9 [1]	0.00144 [3]m	0.00198 [3]m
Furan + Isoprene	70.0 [1]c	0.05 [4]	0.004785 [4]
Benzene	1.2 [1]	0.14 [4]	0.34 [4]
Acrolein	21.7 [1]	0.00083 [3]	0.0033 [3]
Acetone*	0.2 [1]	0.000249 [3]	0.00099 [3]
Acetic acid	0.7 [1]	0.000083 [3]	0.00033 [3]
Toluene	5.6 [1]	0.083 [4]	0.33 [4]
C8 Aromatics	14.2 [1]d	0.047 [4]	0.27 [4]
Dimethyl disulfide	249 [1]		
2-Heptenal	44.0 [1]	0.03 [4]i	0.05 [4]i
C9 Aromatics	22.6 [1]e	0.047 [4]	0.27 [4]
Diallyl disulfide	292.2 [1]		
4-Isopropyl toluene	14.7 [1]	0.07885 [3]	0.27 [3]
Monoterpenes	122.0 [1]f	0.15 [4]	0.15 [4]
2,4-Decadienal	70.5 [2]	0.05 [4]	0.05 [4]
Eucalyptol	22.6 [2]	0.08 [4]n	0.08 [4]n
Eugenol	83.4 [1]	0.3 [4]	0.32 [4]
Cinnamyl acetate	63.6 [2]	0.166 [3]o	0.66 [3]o
Dimethyl sulfide	7.0 [1]		
Octane	7.8 [1]	0.000664 [3]	0.00264 [3]

Nonane	10.2 [1]	0.001577 [3]	0.00627 [3]
Carbon tetrachloride	9.00E-17 [1]		
Maltol	50.1 [2]	0.166 [3]p	0.66 [3]p
Cinnamaldehyde	39.2 [2]	0.166 [3]o	0.66 [3]o
Undecane	11.9 [1]	0.013446 [3]	0.05346 [3]

a: Used OH rate for pyrrole
b: Used OH rate alpha-farnesene
c: Average OH rate of furan and isoprene
d: Average OH rate of xylene isomers and ethylbenzene
e: Average OH rate of trimethylbenzenes, ethyltoluenes and propylbenznene isomers
f: Average OH rate of limonene, α-pinene, β-pinene, camphene, γ-terpinene
g: Based on same SOAP as acrylic acid and toluene
h: Assumed same as oxygenated aliphatics ≥ C6
i: Assumed same as hexanal
j: Based on same SOAP as benzaldehyde and toluene
k: Based on same SOAP as 1-Phenyl-1-butene and toluene
l: Based on same SOAP as Sesquiterpenes and toluene
m: Based on same SOAP as ethanol and toluene
n: Assumed same as monoterpenes
o: Based on same SOAP as 1-Butenylbenzene and toluene
p: Based on same SOAP as Benzene diol isomers and toluene
[1] Mcgillen et al., 2020
[2] EPA, 2024
[3] Based on same SOAP as toluene, Gilman et al., 2015
[4] Stewart et al., 2021

Table S10 Emission rates (µg min^{-1}) of the VOCs measured during the cooking #1 experiments of frying puris in different oils and simply heating the oils without any frying.

Compounds	**Oil heating without puri**							**Frying with puri**						
	Rape seed oil (new)	**Rape seed oil (old)**	**Sun flower oil**	**Olive oil**	**Ground nut oil**	**Coconut oil**	**Ghee**	**Rape seed oil (new)**	**Rape seed oil (old)**	**Sun flower oil**	**Olive oil**	**Ground nut oil**	**Coconut oil**	**Ghee**
Methanol	27.8	23.3	19.2	28.5	15.5	11.4	18.5	208.9	231.4	112.8	153.2	123.1	99.7	114.3
ethanol	34.8	2.9	12.7	57.2	6.7	2.7	50.5	5863.6	5826.9	4344.7	6021.9	5548.3	7781.7	11105.4
1-Propanol	36.9	35.9	28.9	26.8	22.5	4.4	81.8	67.9	87.5	74.2	80.4	51.9	29.8	150.6
Formaldehyde	5.6	2.5	4.6	10.3	3.3	0.0	11.7	35.0	34.2	26.0	31.4	16.3	21.8	37.8
Acetaldehyde	93.2	19.4	29.2	186.4	23.0	16.8	142.1	486.0	443.1	146.1	214.6	75.1	77.1	243.5
Propanal	83.1	16.6	25.7	130.0	25.5	15.3	138.3	296.5	347.9	66.1	99.4	38.3	5.3	179.5
Hexanal	29.2	84.0	35.2	29.8	35.8	8.3	60.5	219.6	219.7	546.2	225.6	223.8	14.2	59.5
Heptanal	29.6	13.9	27.5	31.9	37.6	62.2	151.1	94.8	106.9	81.4	152.9	48.8	6.0	420.2
2-Heptenal	102.4	312.6	89.0	85.9	108.9	4.7	115.8	571.6	657.7	1392.9	640.9	557.1	0.0	80.7
Octanal	8.4	7.9	18.3	11.9	46.1	4.7	61.6	59.1	66.8	29.3	125.4	46.0	3.1	43.9
Nonanal	60.2	47.6	107.6	95.0	213.7	26.4	156.8	479.2	421.0	124.4	742.9	232.3	0.0	119.1
2,4-Decadienal	4.9	30.7	3.3	15.5	12.4	0.0	10.0	2.9	30.2	7.8	10.0	7.7	14.4	4.4
Acetone	7.4	10.7	11.6	8.0	11.9	11.0	33.1	74.6	90.0	46.6	105.0	38.8	31.2	462.5
Acrolein	55.1	43.2	31.8	73.2	27.9	1.9	66.7	258.7	278.0	173.6	125.4	80.5	5.9	80.3
Acetic acid	1.0	0.6	1.1	1.6	1.8	1.3	3.1	4.9	3.6	2.1	5.2	4.9	4.9	3.7
Furan + Isoprene	14.8	8.8	8.4	18.3	9.0	6.1	16.0	20.0	25.6	10.9	14.4	7.1	3.9	10.1
Monoterpenes	1.6	2.4	2.3	3.1	3.2	0.0	3.5	10.2	12.0	18.7	12.2	6.2	7.9	7.3
4-isopropyl toluene	0.5	1.9	1.0	1.5	0.9	0.0	1.1	3.8	4.7	6.1	2.6	3.4	3.0	2.6
Eugenol	0.0	0.0	1.0	0.4	0.9	0.0	0.5	4.0	3.9	0.8	6.5	4.5	2.1	4.3
Eucalyptol	1.5	1.9	3.2	2.9	8.8	0.0	10.0	4.0	10.4	5.3	8.4	9.5	8.4	6.6
Benzoic acid	1.7	6.6	2.3	2.8	1.9	0.2	11.7	5.3	7.6	6.3	4.0	3.3	2.2	4.7

Maltol	5.6	7.7	6.1	7.0	11.0	0.8	16.7	14.0	15.9	14.1	15.0	11.9	1.0	6.0
Cinnamyl acetate	0.0	0.3	1.3	0.0	1.0	0.0	0.4	7.4	6.6	4.2	4.1	6.1	3.1	6.3
Cinnamaldehyde	0.5	0.5	1.3	1.6	1.4	0.0	1.2	6.8	4.4	4.8	6.9	4.0	3.9	4.4
Methyl cinnamate	0.0	0.9	1.9	0.7	1.0	0.0	1.9	5.6	7.4	5.5	9.1	7.8	7.3	4.9
Diallyl disulfide	0.8	1.2	1.0	1.1	2.4	0.3	198.8	3.7	5.1	10.7	5.9	3.8	2.9	538.8
Dimethyl disulfide	1.2	1.9	1.0	1.7	1.7	0.2	2.7	4.9	6.5	7.2	6.1	3.0	2.3	3.4
Dimethyl sulfide	7.1	1.7	3.6	9.2	3.7	0.0	8.7	11.7	13.8	4.2	5.8	3.7	2.1	8.3
Acetonitrile	1.1	0.5	0.6	2.2	0.6	0.3	2.1	7.9	9.3	4.1	4.7	2.3	0.7	9.0
Acrylamide	4.1	4.0	3.4	6.4	3.3	0.0	7.1	29.2	35.7	12.4	16.5	8.3	0.5	10.8
n-Methylpyrrole	1.2	1.7	0.9	1.3	1.2	0.0	1.8	4.4	5.0	5.9	3.4	3.0	0.5	1.2
Benzene	0.7	0.7	0.9	1.9	1.0	0.0	1.1	11.0	8.9	16.8	7.8	2.5	3.6	14.2
Toluene	1.6	1.5	1.6	2.4	1.4	0.1	2.4	2.2	5.0	3.9	4.7	4.9	4.1	4.5
C2-Alkylbenzenes	0.8	2.0	1.3	1.9	3.4	0.7	3.5	2.9	4.1	3.1	4.2	1.5	3.3	2.9
C3-Alkylbenzenes	1.3	2.4	1.8	2.4	2.6	0.0	1.7	4.7	5.3	5.3	4.9	2.4	1.6	5.4
Octane	136.4	2.1	75.2	205.8	67.5	2.7	212.0	533.2	786.0	106.3	687.3	144.3	20.8	186.9
Nonane	412.3	817.2	327.5	533.7	573.9	262.3	910.1	842.4	983.7	1416.5	824.9	615.2	49.9	475.8
Decane	0.0	1.0	2.1	0.8	4.3	0.0	2.1	13.4	12.9	14.8	15.0	7.3	8.7	5.9
Undecane	0.0	3.3	4.7	5.3	16.3	0.0	18.7	4.2	14.7	9.9	12.2	8.4	2.6	7.7
Carbon tetrachloride	9.2	24.6	11.7	14.8	24.5	34.3	1042.7	11.0	17.1	16.4	14.6	11.6	4.8	29.6

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