Supplementary Material

Mitigation of odor and gaseous emissions from the swine barn with UV-A and UV-C photocatalysis

Myeongseong Lee, Jacek A. Koziel\*, Wyatt Murphy, William S. Jenks, Baitong Chen, Peiyang Li, Chumki Banik

Results of targeted gases mitigation under UV photocatalysis

**Table S1.** Mitigation of CH4 with UV-A photocatalysis treatment. Control temperature = 28.5 ± 2.3 ℃, control RH = 69.8 ± 9.5%, treatment temperature: 31.5 ± 1.2 ℃, treatment RH = 66.0 ± 4.3%.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **UV dose  (mJ·cm-2)** | **Light intensity (mW·cm-2)** | **Treatment time (s)** | **Control  (ppm)** | **Treatment  (ppm)** | **% reduction (*p*-value)** |
| UV dose control with light intensity & treatment time | | | | | |
| 1.9 | 0.04 & 0.41 | 15.8 & 3.2 | 7.3 ± 1.3 | 7.1 ± 0.5 | 2.0 (0.83) |
| 2.9 | 0.04 & 0.41 | 23.8 & 4.8 | 7.2 ± 1.0 | 7.8 ± 1.2 | -8.3 (0.08) |
| 2.9 | 0.04 & 0.14 | 43.3 & 8.7 | 19.2 ± 0.4 | 19.1 ± 0.3 | 0.5 (0.77) |
| 4.0 | 0.04 & 0.26 | 43.3 & 8.7 | 19.2 ± 0.4 | 18.7 ± 0.6 | 2.4 (0.11) |
| 5.3 | 0.04 & 0.41 | 43.3 & 8.7 | 5.0 ± 0.2 | 4.8 ± 0.5 | 3.5 (0.69) |

**Table S2.** Mitigation of NH3 with UV-A photocatalysis treatment. Control temperature = 28.5 ± 2.3 ℃, control RH = 69.8 ± 9.5%, treatment temperature: 31.5 ± 1.2 ℃, treatment RH = 66.0 ± 4.3%.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **UV dose  (mJ·cm-2)** | **Light intensity (mW·cm-2)** | **Treatment time (s)** | **Control  (ppm)** | **Treatment  (ppm)** | **% reduction (*p*-value)** |
| UV dose control with light intensity & treatment time | | | | | |
| 1.9 | 0.04 & 0.41 | 15.8 & 3.2 | 24.9 ± 0.4 | 24.6 ± 0.3 | 1.2 (0.14) |
| **2.9** | 0.04 & 0.41 | 23.8 & 4.8 | 20.1 ± 1.1 | 20.2 ± 1.5 | -0.8 (0.14) |
| **2.9** | 0.04 & 0.14 | 43.3 & 8.7 | 26..2 ± 0.5 | 25.8 ± 0.6 | 1.4 (0.07) |
| 4.0 | 0.04 & 0.26 | 43.3 & 8.7 | 22.1 ± 1.0 | 21.9 ± 0.7 | 1.1 (0.36) |
| **5.3** | 0.04 & 0.41 | 43.3 & 8.7 | 15.2 ± 0.4 | 15.2 ± 0.3 | 3.7 (0.08) |

**Table S3.** Mitigation of CH4 with different UV wavelengths irradiating gaseous emissions inside #2 chamber. Air flow = 0.28 m3·s-1, inlet air temperature (influent of chamber #2) = 28 ℃, inlet air RH = 67 %, outlet air temperature (inffluent of chamber #3) = 31 ℃, outlet air RH = 61 %.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **UV Wavelengths  (nm)** | **UV dose  (µJ·cm-2)** | **Light intensity (µW·cm-2)** | **Control  (ppm)** | **Treatment  (ppm)** | **% reduction (*p*-value)** |
| 185 + 254 | 0.03 µJ∙cm-2 | 0.01 | 9.4 ± 1.5 | 10.7 ± 1.6 | -13.4 (0.13) |
| 222 | 2.55 µJ∙cm-2 | 0.59 | 10.0 ± 0.6 | 9.2 ± 3.6 | 8.4 (0.75) |
| 254 | 1.60 µJ∙cm-2 | 0.37 | 10.2 ± 0.5 | 11.6 ± 2.7 | -14.3 (0.51) |
| 367 | 1,775 µJ∙cm-2 | 410 | 10.1 ± 0.2 | 10.3 ± 1.5 | -2.7 (0.80) |

**Table S4.** Mitigation of CO2 with different UV wavelengths irradiating gaseous emissions inside #2 chamber. Air flow = 0.28 m3·s-1, inlet air temperature (influent of chamber #2) = 28 ℃, inlet air RH = 67 %, outlet air temperature (inffluent of chamber #3) = 31 ℃, outlet air RH = 61 %.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **UV Wavelengths  (nm)** | **UV dose  (µJ·cm-2)** | **Light intensity (µW·cm-2)** | **Control  (ppm)** | **Treatment  (ppm)** | **% reduction (*p*-value)** |
| 185 + 254 | 0.03 µJ∙cm-2 | 0.01 | 774 ± 107 | 929 ± 40 | -20.1 (0.06) |
| 222 | 2.55 µJ∙cm-2 | 0.59 | 823 ± 44 | 849 ± 39 | -3.1 (0.07) |
| 254 | 1.60 µJ∙cm-2 | 0.37 | 835 ± 27 | 845 ± 65 | -1.2 (0.70) |
| 367 | 1,775 µJ∙cm-2 | 410 | 853 ± 6.8 | 867 ± 29 | -1.7 (0.43) |

**Table S5.** Mitigation of odor with different UV wavelengths irradiating gaseous emissions inside #2 chamber. Air flow = 0.28 m3·s-1, inlet air temperature (influent of chamber #2) = 28 ℃, inlet air RH = 67 %, outlet air temperature (inffluent of chamber #3) = 31 ℃, outlet air RH = 61 %.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **UV Wavelengths  (nm)** | **UV dose  (µJ·cm-2)** | **Light intensity (µW·cm-2)** | **Control  (OUE∙m-3)** | **Treatment  (OUE∙m-3)** | **% reduction (*p*-value)** |
| 185 + 254 | 0.03 µJ∙cm-2 | 0.01 | 369 ± 29 | 402 ± 54 | -8.7 (0.35) |
| 222 | 2.55 µJ∙cm-2 | 0.59 | 352 ± 65 | 455 ± 56 | -29.4 (0.19) |
| 254 | 1.60 µJ∙cm-2 | 0.37 | 347 ± 29 | 459 ± 92 | -32.1 (0.27) |
| 367 | 1,775 µJ∙cm-2 | 410 | 257 ± 87 | 237 ± 19 | 7.8 (0.77) |

**Table S6.** Mitigation of odorous VOCs with different UV wavelengths irradiating gaseous emissions inside #2 chamber. Air flow = 0.28 m3·s-1, inlet air temperature (influent of chamber #2) = 28 ℃, inlet air RH = 67 %, outlet air temperature (inffluent of chamber #3) = 31 ℃, outlet air RH = 61 %.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Type of VOCs** | **Percent reduction (*p*-value)** | | | |
| **UV-C dose, µJ·cm-2  (light intensity, µW·cm-2)** | | | **UV-A dose, µJ·cm-2  (light intensity, µW·cm-2)** |
| **185 + 254 nm 0.03 (0.01)** | **222 nm 2.55 (0.59)** | **254 nm 1.60 (0.37)** | **367 nm 1,775 (410)** |
| DMDS | -15.7 (0.86) | -16.9 (0.77) | -33.3 (0.71) | 7.3 (0.41) |
| DEDS | Not detected | Not detected | Not detected | Not detected |
| Acetic acid | -66.1 (0.40) | -7.5 (0.94) | -33.2 (0.72) | -0.6 (0.98) |
| Propanoic acid | -21.5 (0.78) | -12.0 (0.75) | -49.6 (0.59) | -11.8 (0.32) |
| Isobutyric acid | 33.6 (0.58) | 11.8 (0.85) | 10.3 (0.32) | -13.1 (0.78) |
| Butanoic acid | -7.3 (0.93) | 1.6 (0.98) | -13.6 (0.83) | 14.1 (0.70) |
| Isovaleric acid | -12.3 (0.74) | -7.4 (0.90) | -30.1 (0.70) | -10.8 (0.88) |
| Valeric acid | -29.5 (0.74) | -23.3 (0.77) | -33.7 (0.50) | -21.7 (0.70) |
| Hexanonic acid | -30.4 (0.24) | -55.5 (0.29) | -37.0 (0.50) | 15.0 (0.47) |
| Phenol | -10.0 (0.63) | -4.0 (0.90) | -31.6 (0.40) | 0.5 (0.98) |
| *p*-Cresol | 49.6 (0.27) | -0.7 (0.99) | -58.2 (0.43) | 13.5 (0.24) |
| Indole | -2.3 (0.97) | 26.5 (0.49) | -0.6 (0.99) | 4.0 (0.88) |
| Skatole | 16.5 (0.73) | -8.8 (0.54) | -31.7 (0.53) | -21.2 (0.43) |

DMDS = dimethyl disulfide; DEDS = diethyl disulfide.

**Table S7.** Mitigation of NH3 with different UV wavelengths irradiating gaseous emissions inside #2 chamber. Air flow = 0.28 m3·s-1, inlet air temperature (influent of chamber #2) = 28 ℃, inlet air RH = 67 %, outlet air temperature (inffluent of chamber #3) = 31 ℃, outlet air RH = 61 %.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **UV Wavelengths  (nm)** | **UV dose  (µJ·cm-2)** | **Light intensity (µW·cm-2)** | **Control  (ppm)** | **Treatment  (ppm)** | **% reduction (*p*-value)** |
| 185 + 254 | 0.03 µJ∙cm-2 | 0.01 | 14.4 ± 1.1 | 14.4 ± 1.2 | -0.4 (0.82) |
| 222 | 2.55 µJ∙cm-2 | 0.59 | 16.1 ± 0.8 | 16.4 ± 0.4 | -2.2 (0.09) |
| 254 | 1.60 µJ∙cm-2 | 0.37 | 16.9 ± 0.4 | 17.0 ± 0.3 | -0.8 (0.06) |
| 367 | 1,775 µJ∙cm-2 | 410 | 16.6 ± 0.3 | 16.6 ± 0.3 | 0.3 (0.70) |

**Table S8.** Mitigation of H2S with different UV wavelengths irradiating gaseous emissions inside #2 chamber. Air flow = 0.28 m3·s-1, inlet air temperature (influent of chamber #2) = 28 ℃, inlet air RH = 67 %, outlet air temperature (inffluent of chamber #3) = 31 ℃, outlet air RH = 61 %.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **UV Wavelengths  (nm)** | **UV dose  (µJ·cm-2)** | **Light intensity (µW·cm-2)** | **Control  (ppm)** | **Treatment  (ppm)** | **% reduction (*p*-value)** |
| 185 + 254 | 0.03 µJ∙cm-2 | 0.01 | 1.5 ± 0.1 | 1.6 ± 0.2 | -6.9 (0.82) |
| 222 | 2.55 µJ∙cm-2 | 0.59 | 1.6 ± 0.2 | 1.6 ± 0.3 | 2.1 (0.70) |
| 254 | 1.60 µJ∙cm-2 | 0.37 | 1.7 ± 0.1 | 1.7 ± 0.1 | -2.2 (0.27) |
| 367 | 1,775 µJ∙cm-2 | 410 | 16.6 ± 0.3 | 2.3 ± 0.2 | 1.0 (0.71) |

**Table S9.** Performance of UV-A photocatalysis in mitigating CH4 concentrations under different PM conditions. UV-A dose: 5.3 mJ∙cm-2, Airflow = 0.28 m3·s-1.

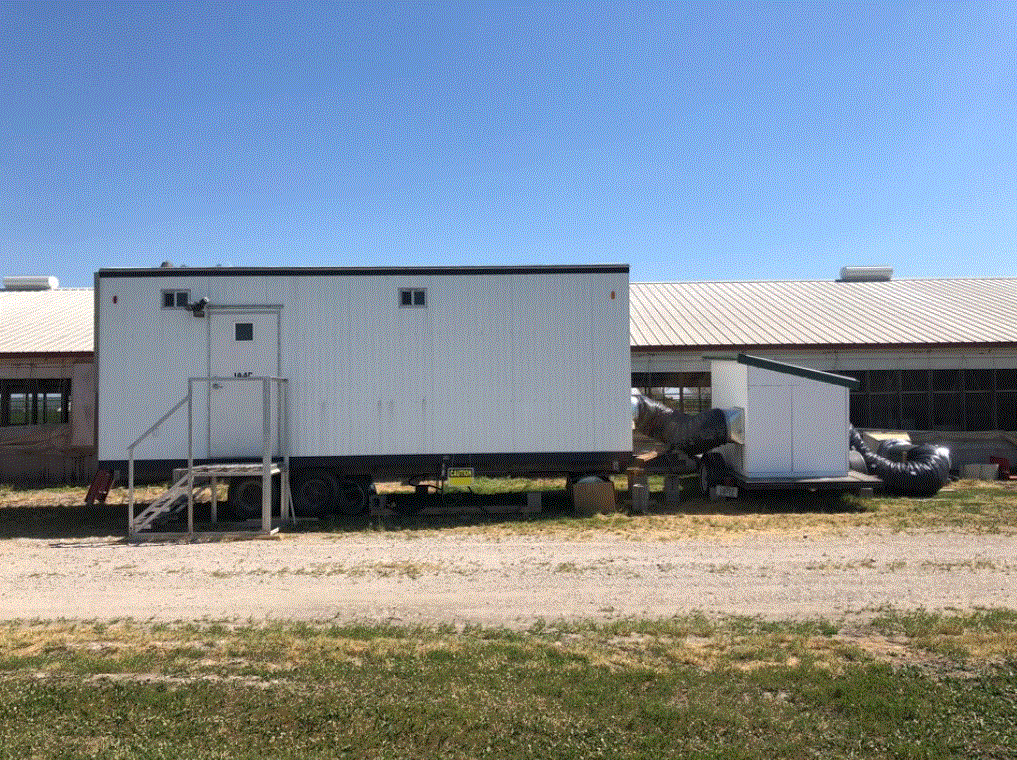
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Total PM concentration (mg∙m-3)** | **UV dose  (mJ·cm-2)** | **Control  (ppb)** | **Treatment  (ppb)** | **% reduction (*p*-value)** |
| 0.22 | 5.3 | 22.0 ± 2.6 | 21.6 ± 0.2 | 1.9 (0.82) |
| 0.06 | 5.3 | 16.5 ± 3.0 | 15.5 ± 2.0 | 5.6 (0.78) |
| 0.004 | 5.3 | 5.0 ± 0.2 | 5.2 ± 0.1 | -4.2 (0.38) |

**Table S10.** Performance of UV-A photocatalysis in mitigating CO2 concentrations under different PM conditions. UV-A dose: 5.3 mJ∙cm-2, Airflow = 0.28 m3·s-1. **Bold** signifies statistical significance.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Total PM concentration (mg∙m-3)** | **UV dose  (mJ·cm-2)** | **Control  (ppb)** | **Treatment  (ppb)** | **% reduction (*p*-value)** |
| 0.22 | 5.3 | 967 ± 127 | 1036 ± 21 | -7.2 (0.50) |
| 0.06 | 5.3 | **705 ± 33** | **789 ± 27** | **-11.9 (0.02)** |
| 0.004 | 5.3 | 1201 ± 296 | 1483 ± 91 | -26.5 (0.15) |

**Table S11.** Performance of UV-A photocatalysis in mitigating NH3 concentrations under different PM conditions. UV-A dose: 5.3 mJ∙cm-2, Airflow = 0.28 m3·s-1. **Bold** signifies statistical significance.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Total PM concentration (mg∙m-3)** | **UV dose  (mJ·cm-2)** | **Control  (ppm)** | **Treatment  (ppm)** | **% reduction (*p*-value)** |
| 0.22 | 5.3 | 28.5 ± 0.3 | 28.4 ± 0.3 | 0.3 (0.67) |
| 0.06 | 5.3 | 18.2 ± 0.6 | 18.3 ± 0.9 | -0.4 (0.75 |
| 0.004 | 5.3 | 15.0 ± 0.4 | 14.8 ± 0.3 | 1.9 (0.12) |



**Figure S1**. Picture of mobile laboratory arrangement outside swine farm.



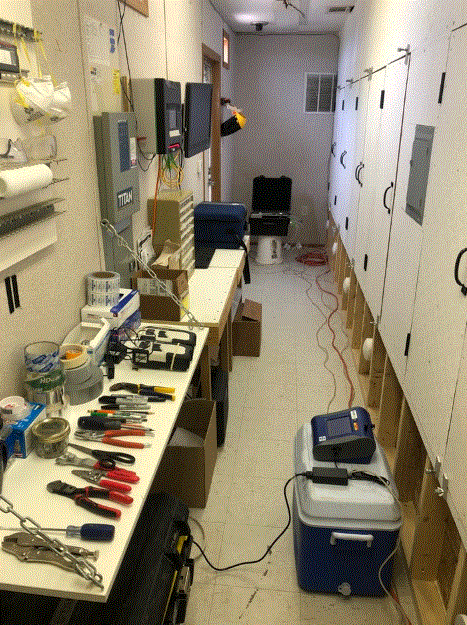
**Figure S2**. Picture of connecting the exhaust fan, T duct, and filtration unit using the flexible duct. The flexible duct is insulated and plastic-wrapped to protect from punctures and weather.



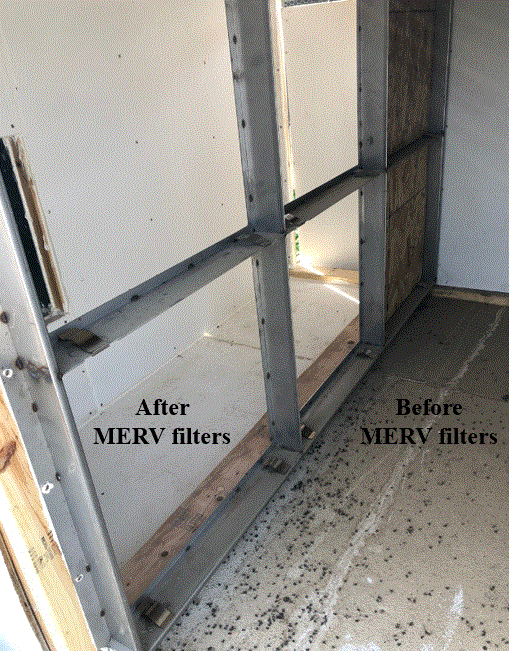
**Figure S3**. Picture of connecting filtration unit and the mobile laboratory using the flexible duct.



**Figure S4**. Picture of the chamber with photocatalysis panels and UV-A LED lamps attached inside the mobile laboratory.



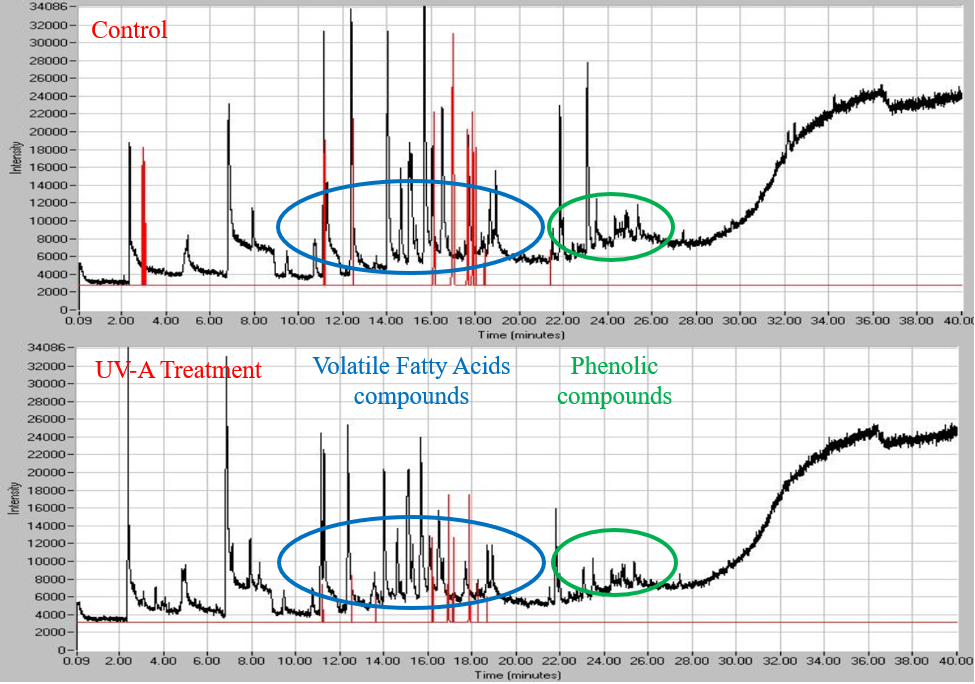
**Figure S5**. Picture of inside view in the mobile laboratory. (a): before installing the portable lamp holder (seen in the far back), (b): during measurements of targeted gases.

****

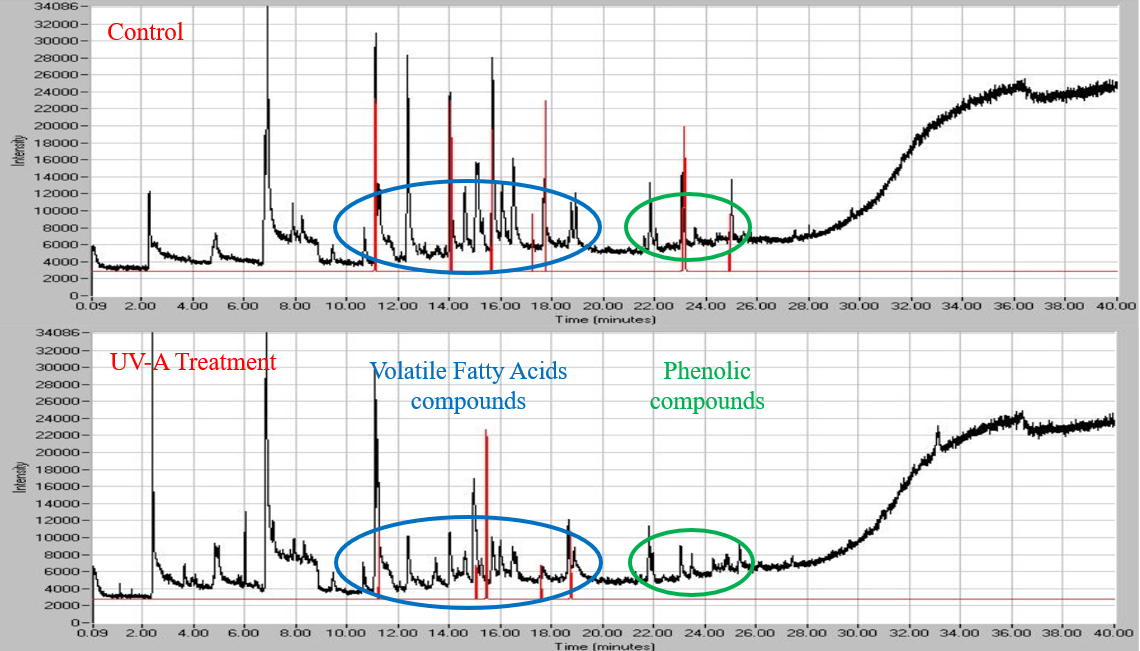
**Figure S6**. Picture of inside the filtration unit with the MERV filters removed to show more details. Black dots on the floor are flies on the inlet side.



**Figure S7**. Picture of the sampling of formaldehyde concentration with colorimetric tube and the Gastec pump kit.



**Figure S8.** An overlay of the chromatogram (black line) and aromagram (red line) for panelist 1. The height of aromagram peaks represents measured odor intensity (percent relative scale). The TIC signal is collected simultaneously, enabling linking odors to specific chemicals. Several unpleasant (out of 31 total) odors were recorded during analysis with GC-MS-Olfactometry, and few of them were medium-to-strong intensity.



**Figure S9.** An overlay of the chromatogram (black line) and aromagram (red line) for panelist 2. The height of aromagram peaks represents measured odor intensity (percent relative scale). The TIC signal is collected simultaneously, enabling linking odors to specific chemicals. Several unpleasant (out of 31 total) odors were recorded during analysis with GC-MS-O, and few of them were medium-to-strong intensity.