Electronic Supplementary Information for

Indoor particulate matter (PM) from cooking in UK students' studio flats and associated intervention strategies: evaluation of cooking methods, PM concentrations and personal exposures using low-cost sensors.

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Overview of the Electronic Supplementary Information:

S1. Further Study Details

The five studied kitchen were in student accommodations near the University of Birmingham. As all the study kitchens were part of 'studio accommodation', the volume of kitchens could be counted as the volume of the studios A-E excluding the bathrooms. These were 42.84 m^3, 50.96 m^3, 42.56 m^3, 35.84 m^3, 46.76 m^3, respectively. The locations of studied kitchens of student accommodations A-E were displayed in Figure S1.
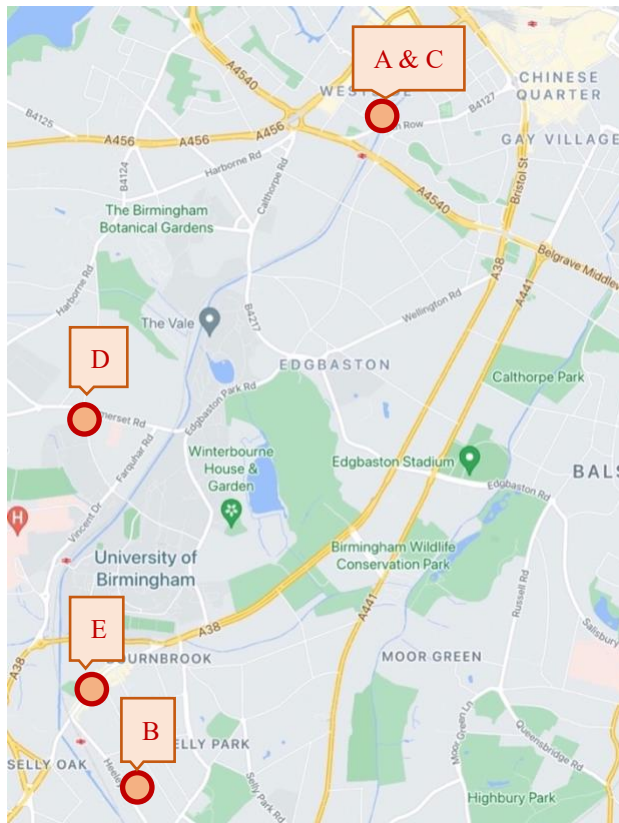

Figure S1. Locations of the five study sites within student accommodation near the University of Birmingham, UK.[1]

Figure S2. Picture of the Flow2.

S2. Definitions of Studied Cooking Methods

Deep-frying is a method of cooking to submerge food in hot fat, most commonly oil, which cooks all sides of the food simultaneously. Stir-frying is the cooking method which fries ingredients in a small amount of very hot oil while being stirred in a wok or pan. Boiling is a cooking method that includes braising, decoction and simmering, which makes soup or boils ingredients in water or broth. Steaming is a way of cooking by using steam to heat food.

The four typical dishes which represented the four cooking examples were deep-fried chicken, stir-fried chicken, chicken soup and steamed chicken. The same food (100g boneless chicken thigh) was used in each cooking activities. The cookware was a 20cm / 3.6L non-stick forged aluminium stockpot. The cooking processes were listed below.

- Deep-fried chicken

    2L grapeseed oil was heated in the pot for three minutes until 160˚C, and the sliced chicken thigh was deep-fried with was seasoned by salts for ten minutes when the chicken was in golden colour.

- Stir-fried chicken

    30mL grapeseed oil was heated in the pot for one minute until 180˚C, and the sliced chicken thigh was quickly fried for five minutes with only salt added.

- Chicken soup

    800mL water was heated for four minutes until 70˚C, and the sliced chicken was added. After boiling and skimming off the scum (four minutes), it kept boiling for another four minutes with only salt added.

- Steaming chicken

    800mL water was heated for six minutes until boiling, the sliced chicken was seasoned with salt and placed in plate to be steamed for 13 minutes.

Figure S3. Survey for the recording of cooking activities. This is a sample of the survey of one day. Volunteers were asked to fill in the blanks and tick the cooking methods they chose to record the information of each cooking activities.

S3. Flow2 Accuracy Assessment

The accuracy of the Flow2 were examined by co-location with a Fidas 200, the reference instrument, in an office in Bioscience Building, University of Birmingham, UK. Two Flow2 sensors have been placed for one week, and ensured sufficient automatic synchronisations (at least twice a day) between the Flow2 sensors and applications on devices via the connection of Bluetooth, which was advised by the manufacturer. The recorded data of indoor air PM concentration from 12.22pm to 23:59 on 3rd of October, 2022, were chosen to be assessed, due to some happened in the room which caused significant changes on PM concentrations. Based on similar studies, the Coefficient of Variation (CV) or Relative Standard Deviation, which determined the variation among the sensors, Relative Precision Errors (RPE), which would be averaged to indicate the precision of the sensors, and Accuracy (Acc) by comparisons between Flow2 and Fidas 200 were calculated and linear regressions were chosen to yield the R2 correlation between the two Flow2 sensors and between each Flow2 sensor and Fidas 200 were conducted by SPSS (IBM version 28).[2-4]

The coefficient of variation (CV) examined the precision of the measurement by the various sensors. For each sensors, based on the time resolution of Flow2, the recording of every one minute was determined as a sample, which CV is calculated:

$$CV = \frac{\sigma}{\mu}$$
<div align="right">**(Equation S1)**</div>

where σ and μ were, respectively, the standard deviation and mean of the concentration recording by the two Flow2 sensors at each time point.[2] Then the CVs of PM_{10} and $PM_{2.5}$ were averaged for the duration of the assessment.

The relative precision errors (RPE) demonstrated the precision of PM concentration between the pair of Flow2 sensors that were functioning over the course of the assessment for the recording every minute (Equation S2):

$$RPE = \left| \frac{sensor1 - sensor2}{average(sensor1, sensor2)} \right|$$
<div align="right">**(Equation S2)**</div>

Then the REP was averaged as well. A value of RPE close to 0 could determine a perfect precision.[3]

The accuracy (Acc) of Flow2 sensors was evaluated by comparing to Fidas® 200, the reference, which was assessed by using Equation S3 to determine the accuracy of each Flow2 sensor:

$$Acc = 1 - \left| \frac{reference - sensor}{sensor} \right|$$
<div align="right">**(Equation S3)**</div>

Then the accuracies were averaged to determine the overall accuracy of each Flow2 sensor.[3]
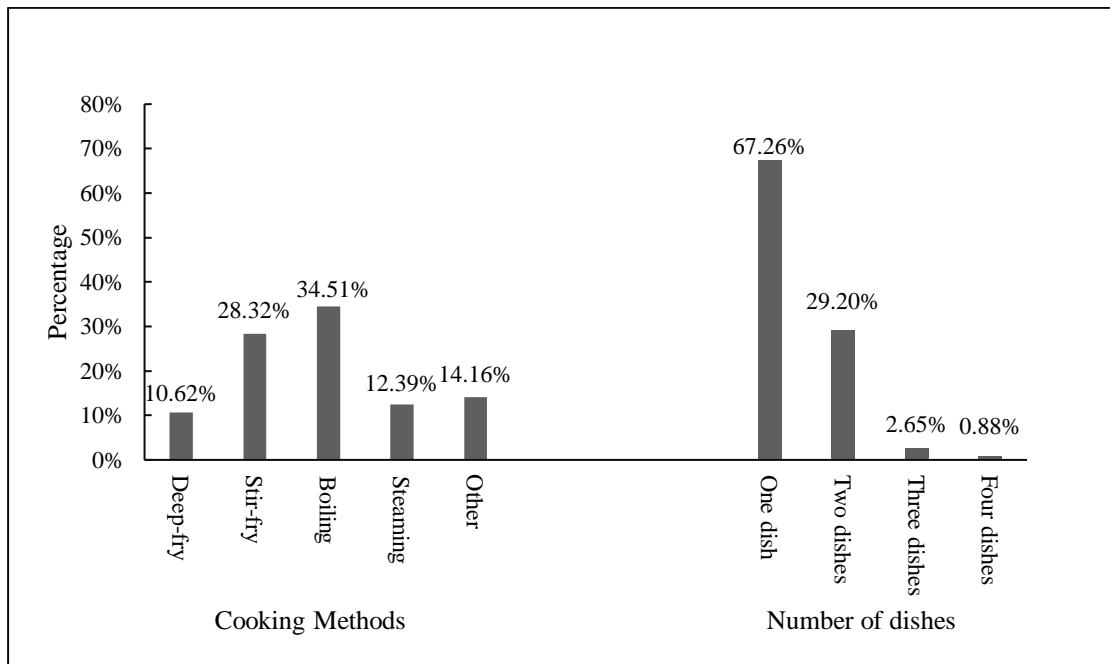
Figure S4. The results of the proportion (percentage) of each cooking method and the number of dishes from the questionnaire survey for the studied student cooking.
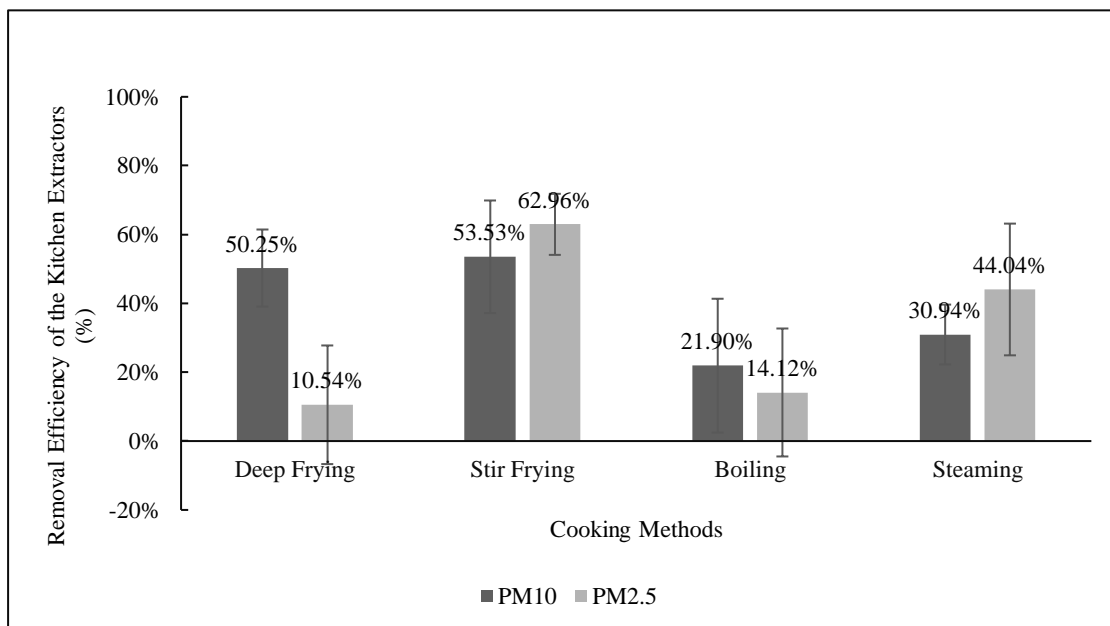

Figure S5. Particulate matter removal efficiency by kitchen extractors during various cooking methods (error bars indicated standard deviations).

References

1. Google, Maps of Edgbaston, Birmingham, http://maps.google.co.uk, (accessed 20 June, 2021).
2. F. M. J. Bulot, H. S. Russell, M. Rezaei, M. S. Johnson, S. J. J. Ossont, A. K. R. Morris, P. J. Basford, N. H. C. Easton, G. L. Foster, M. Loxham and S. J. Cox, *Sensors*, 2020, **20**.

3.   N. Crnosija, M. Levy Zamora, A. M. Rule and D. Payne-Sturges, *International Journal of Environmental Research and Public Health*, 2022, **19**.

4.   M. Levy Zamora, F. Xiong, D. Gentner, B. Kerkez, J. Kohrman-Glaser and K. Koehler, *Environmental Science & Technology*, 2018, **53**, 838-849.