

Nanoparticle emissions from cooking measured in real-time

Introduction

As domestic buildings are increasingly well sealed in the interests of energy efficiency, the release of particles from activities inside buildings may result in increased exposure to the occupants. Cooking of foodstuffs, although carried out in many countries with clean fuels such as electricity or gas, can itself be a significant source of particles.

Cooking can be an event of relatively short duration, and the operator can be quite close to the source of particles during short periods of interaction with the food (turning etc.) which can lead to short lived peaks in particle emissions with consequent high exposure.

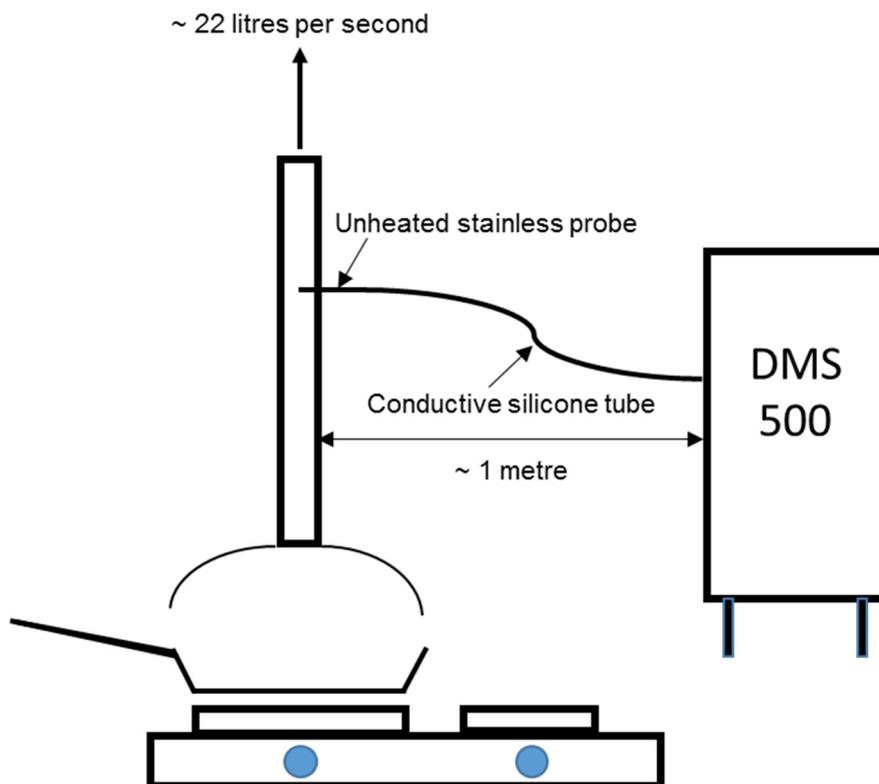
DMS500 Fast Particulate Spectrometer

The DMS500 Fast Particulate Spectrometer uses unipolar corona charging and parallel detection of particles of varying electrical mobility (using electrometers) to offer real-time measurement of the particle size spectrum between 5 and 2,500 nm.

Various design features allow the instrument to offer 10 Hz data with a $T_{10-90\%}$ of 200 ms, which is well suited to the short transient nature of emissions.

Sampling Arrangements

An electric hotplate of power 1,500W was located under an extraction hood. The total flow through the extraction hood was fixed at ~22 litres per second. (Constant Volume Sampling.) This ensures that all the particles produced by the cooking process are captured by the hood, and allows calculation of emission rates for total particle number and mass.



A DMS500 set to measure between 5nm and 1,000nm at 10Hz was connected downstream of the extraction hood (more than 10 diameters to ensure the dilution air and cooking products are fully mixed), drawing a sample flow of approximately 8 litres per minute. The sampling tube length was approximately 1 metre.

Example Data

The following plots show various stages in the cooking of a burger.

Adding a burger:

The frying pan was placed on the hotplate with a small amount of oil, and the two allowed to warm up until the oil wetted the pan.

During this period (shown prior to 180 seconds), the background particle concentration was clearly visible at around 20,000 N/cc.

No correction for background measurements has been applied to the following data, since the emissions during cooking are orders of magnitude higher than those observed in the background.

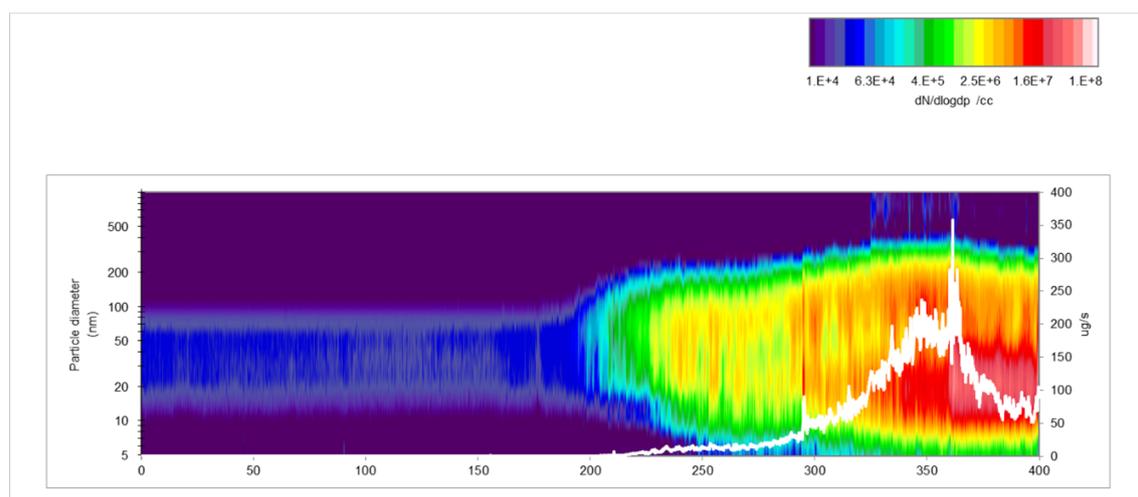


Figure 1: Background, pre-heating and initial cooking

After around two minutes of pre-heating, a burger was added to the pan. A bimodal spectrum develops over the next two minutes, with CMDs of approximately 25 and 70 nm. No firm conclusions can be drawn about the composition of the two modes, but the high flow rate (22 litres / second) of dilution air means that condensation of water is unlikely. The aerosol is relatively unstable on a second-to-second and sub-second basis.

Nanoparticle spectra

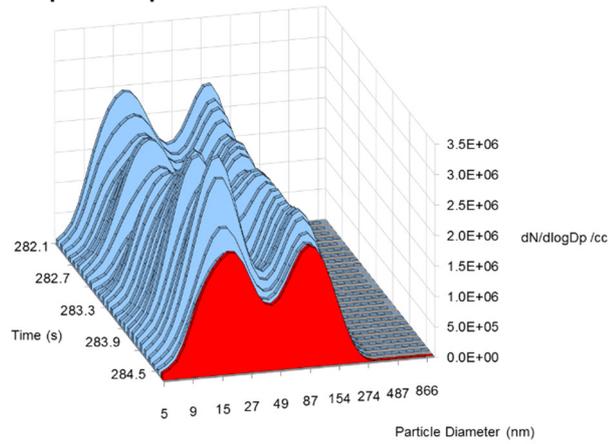


Figure 2: Bimodal spectra during cooking process

This observed, unstable bi-modal aerosol may be due to dilution effects, but may also be due to local heating effects at the pan/food interface.

Around two minutes after the burger was added to the hot pan, the pan was agitated by hand at around 295 seconds.

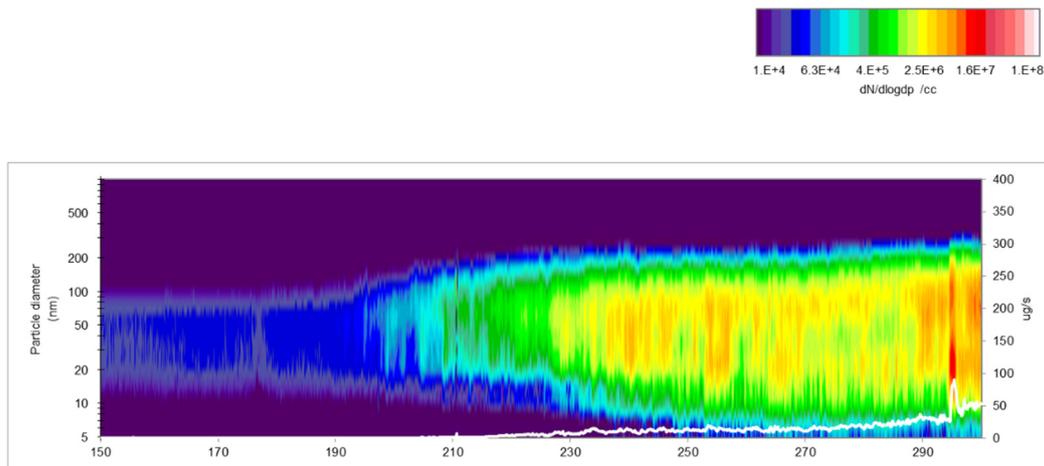


Figure 3: Initial cooking and agitation of burger

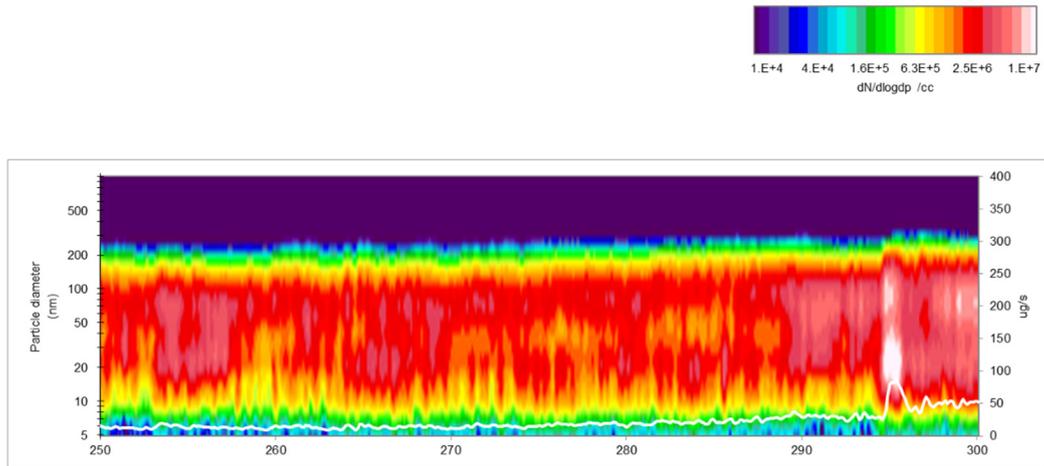


Figure 4: Highlight of burger agitation

This produces a short burst of ultrafine nanoparticles tripling the mass emission rate for a short period of time. Since this increase takes place while the operator is close to the hob, effective exposure to such events may be assumed to be high. The smaller ~20 nm mode increases greatly in concentration, while the larger mode not only increases in concentration but experiences a CMD shift from ~ 70 nm to 90 nm.

Both of these events are very short duration (less than 2 seconds) and the aerosol returns very quickly to the previous state once the agitation of the pan stops.

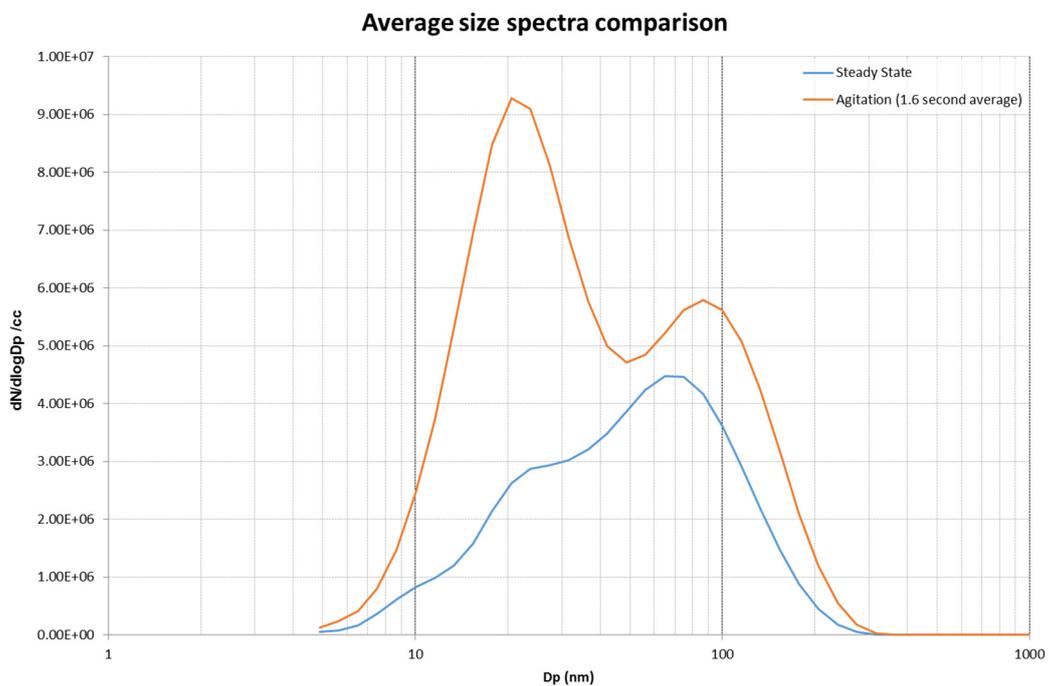


Figure 5: Comparison of spectra during steady state and agitation

An approximation to mass concentration was derived by weighting the spectrum, assuming spherical particles and unit density. The initial period is notable for high mass emissions.

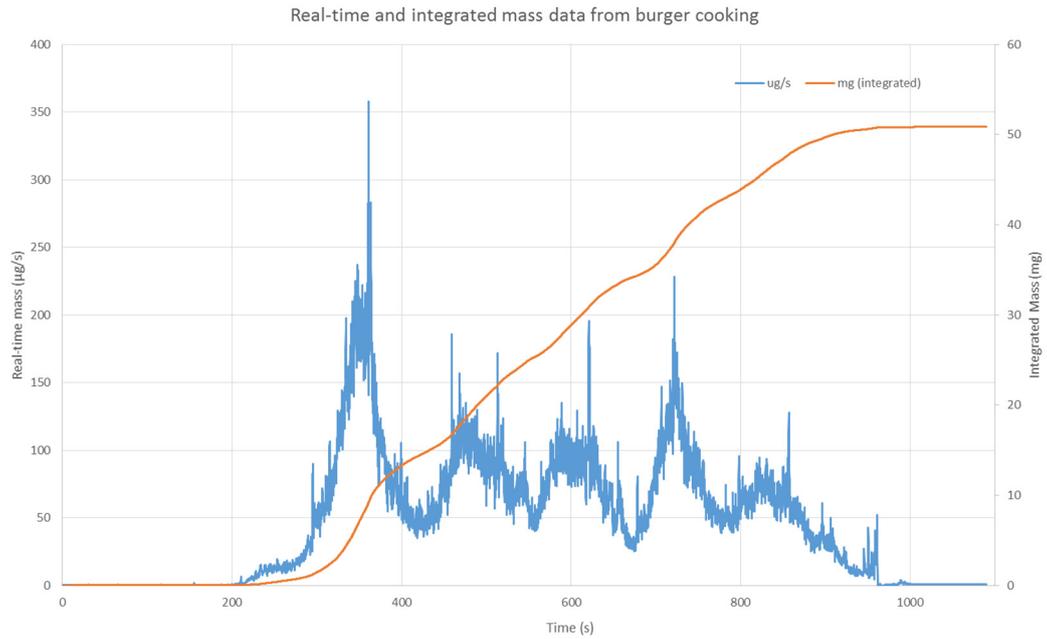


Figure 6: Real-time and integrated mass emissions

The total particulate mass released during the cooking of one burger is calculated as approximately 50 mg. In the absence of extraction, the aerosol particles may be presumed to persist in the building, until they are lost onto surfaces, or are inhaled.

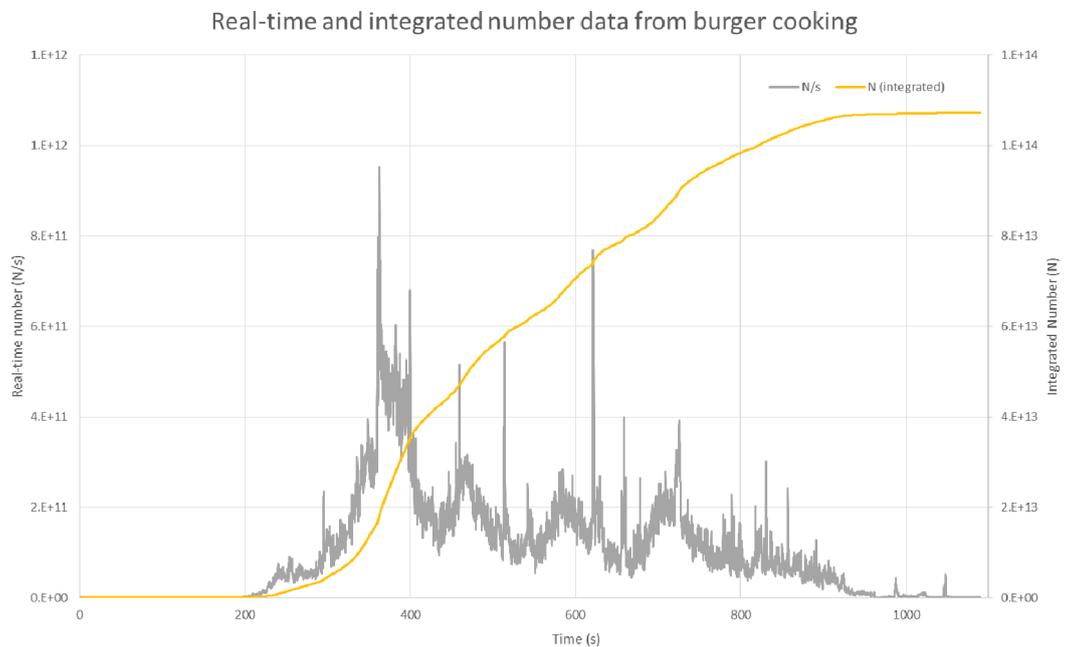


Figure 7: Real-time and integrated number emissions

The observed cyclical effect in both number and mass emissions (with approximate period 120 seconds) corresponds well with the cycling of the thermostatic control of the hotplate. A thermocouple to measure the temperature of the cooking surface would give extra insight into the magnitude of temperature change associated with the significant changes in particle output.

Conclusions

The DMS500 is able to accurately resolve the size distribution of nanoparticles produced by cooking processes, including the short lived transients associated with manipulating the food.

The DMS500's high time resolution (the above data was logged at 10 Hz) provides excellent opportunities to look at these transient events in greater detail.

The shifts in the modal size distribution seen during periods of agitation when the operator is close to the hotplate are of particular interest, since direct exposure will be high during these periods.

The Constant Volume Sampling technique used allows direct calculation of the total particulate number and mass released during the cooking process. This can be combined with mixing and loss models to establish exposure for other occupants of a room or building.

Further Reading:

DMS500: www.cambustion.com/products/dms500/aerosol

“Size distribution and emission rate measurement of fine and ultrafine particle from indoor human activities”
Atmospheric Environment 42(35):8341-8352, <http://dx.doi.org/10.1016/j.atmosenv.2008.07.021>