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Operating Agent
and Management
Boulevard Poincaré 79
B-1060 Brussels – Belgium
inive@bbri.be - www.inive.org

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Air Infiltration and Ventilation Centre

Residential Cooker Hoods

Iain Walker, LBNL, USA
Benjamin Jones, University of Nottingham, UK
Wouter Borsboom, TNO, Netherlands

1 Introduction

Cooking is a major source of contaminants in homes and contributes to three major indoor air quality (IAQ) issues: odours, moisture and health. Odour control has traditionally been the basis for many ventilation requirements and a key aspect of acceptable IAQ. Controlling the moisture content of indoor air is essential for comfort and to prevent mould and condensation and has been the main reason for kitchen exhaust ventilation requirements in building regulations. In recent years, the negative health effects caused by exposure to indoor air contaminants has enabled the identification of *contaminants of concern* [12]. Many are generated by cooking, in particular particulate matter (PM) and NO_2. Recent advances in sensors that detect these contaminants have enabled field and laboratory studies to better understand their emission rates and resulting concentrations. This knowledge has led to an increased interest in using ventilation and source control to minimize exposure to them. The most effective ventilation strategy is to use a cooker hood to directly extract contaminants outside. Accordingly, this VIP summarizes current knowledge on cooking contaminant emissions, its effects on IAQ, and identifies standards for assessing the efficacy of cooker hood (also known as a *range* hood) performance.

2 Health-related cooking contaminants

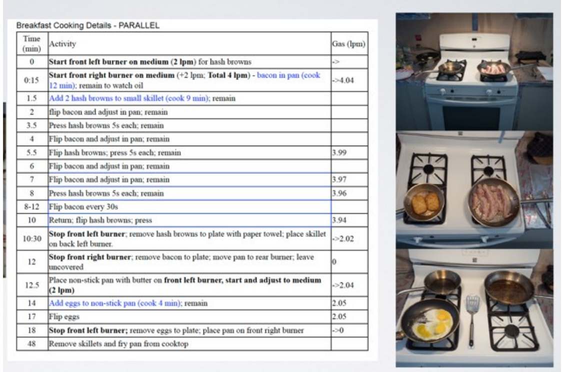
Contaminants are emitted from both the heat source and the food itself. The cooking of the food produces H_2O, PM and odours and depends on the cooking activity: boiling water produces water vapour and frying produces PM.

The source of heat for cooking significantly changes the emission of contaminants of concern that affect health; for example, burning gas creates CO_2, H_2O, NO_2, and acrolein that electric and induction cooking do not. Poor combustion can produce carbon monoxide (CO). The emission rate of CO is often high when a gas oven ignites, even when it operates correctly [14]. Gas burning generates nearly no fine particles ($PM_{2.5}$), however it does generate significant numbers of ultra-fine particles ($PM_{0.1}$) [27]. An electric cooktop (also known as a *hob*) can also produce large quantities of particulates (PM). An induction cooktop reduces PM emission [15] because it operates at lower temperatures. Some experiments show reductions in PM emissions if non-stick pans are used [11, 13].

Researchers have standardized cooking for valuation purposes. Some studies have attempted to understand the repeatability of contaminant emission rate measurement methods and the uncertainty in the emission rates during cooking [25]. This was done by repeatedly toasted pre-sliced bread because it is a simple and repeatable cooking process. It showed that the variance in the rate $PM_{2.5}$ are emitted is high. It also shows that $PM_{2.5}$ are neither emitted continuously during a cooking process nor at a constant rate.

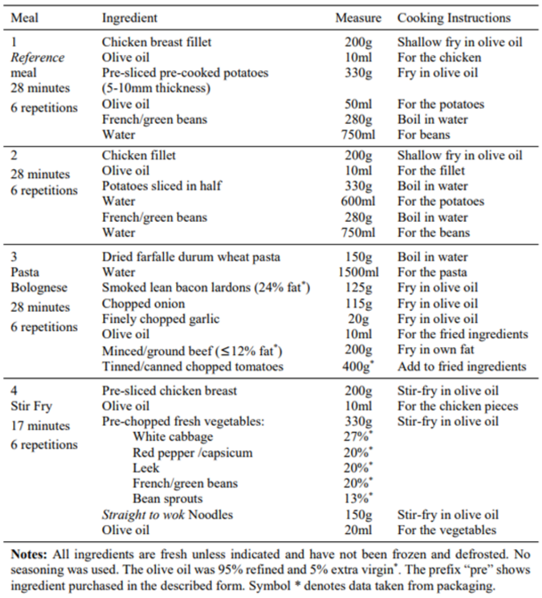
Other experimental studies [7, 8, 11] used field studies and scripted meals in laboratory kitchens to perform controlled evaluations of contaminant emissions (see Figures 1 & 2) from the cooking of entire meals. Contaminant emission rates vary considerably for each of the different meals cooked, although many factors that might affect them are difficult to quantify. However, factors that clearly do influence contaminant emission rates are the browning of food, the presence of oil or fat, frying, high pan temperatures, and the use of pans without a non-stick coating [11].

Confounding issues were identified with the calibration of optical devices that require a *calibration factor* to correct for changes in the physical and optical properties of measured particles from those of the PM used to calibrate the device. The calibration factor varies by meal. The properties of PM emitted by cooking are also found to be important when choosing a low-cost detection device to automate a system [28]; see Section 5. Ideally, they have to be able to be able to detect $PM_{0.1}$ or they will miss important sources.


Breakfast Cooking Details - PARALLEL

Time (min)	Activity	Gas (lpm)
0	**Start front left burner on medium (2 lpm)** for hash browns	->
0:15	**Start front right burner on medium** (+2 lpm; **Total 4 lpm**) - bacon in pan (cook 12 min); remain to watch oil	->4.04
1.5	Add 2 hash browns to small skillet (cook 9 min); remain	
2	flip bacon and adjust in pan; remain	
3.5	Press hash browns 5s each; remain	
4	Flip bacon and adjust in pan; remain	
5.5	Flip hash browns; press 5s each; remain	3.99
6	Flip bacon and adjust in pan; remain	
7	Flip bacon and adjust in pan; remain	3.97
8	Press hash browns 5s each; remain	3.96
8-12	Flip bacon every 30s	
10	Return; flip hash browns; press	3.94
10:30	**Stop front left burner**; remove hash browns to plate with paper towel; place skillet on back left burner.	->2.02
12	**Stop front right burner**; remove bacon to plate; move pan to rear burner; leave uncovered	0
12.5	Place non-stick pan with butter on **front left burner, start and adjust to medium (2 lpm)**	->2.04
14	Add eggs to non-stick pan (cook 4 min); remain	2.05
17	Flip eggs	2.05
18	**Stop front left burner;** remove eggs to plate; place pan on front right burner	->0
48	Remove skillets and fry pan from cooktop	

Figure 1: Scripted cooking events at LBNL



Meal	Ingredient	Measure	Cooking Instructions
1 *Reference* meal 28 minutes 6 repetitions	Chicken breast fillet	200g	Shallow fry in olive oil
	Olive oil	10ml	For the chicken
	Pre-sliced pre-cooked potatoes (5-10mm thickness)	330g	Fry in olive oil
	Olive oil	50ml	For the potatoes
	French/green beans	280g	Boil in water
	Water	750ml	For beans
2 28 minutes 6 repetitions	Chicken fillet	200g	Shallow fry in olive oil
	Olive oil	10ml	For the fillet
	Potatoes sliced in half	330g	Boil in water
	Water	600ml	For the potatoes
	French/green beans	280g	Boil in water
	Water	750ml	For the beans
3 Pasta Bolognese 28 minutes 6 repetitions	Dried farfalle durum wheat pasta	150g	Boil in water
	Water	1500ml	For the pasta
	Smoked lean bacon lardons (24% fat*)	125g	Fry in olive oil
	Chopped onion	115g	Fry in olive oil
	Finely chopped garlic	20g	Fry in olive oil
	Olive oil	10ml	For the fried ingredients
	Minced/ground beef (≤12% fat*)	200g	Fry in own fat
	Tinned/canned chopped tomatoes	400g*	Add to fried ingredients
4 Stir Fry 17 minutes 6 repetitions	Pre-sliced chicken breast	200g	Stir-fry in olive oil
	Olive oil	10ml	For the chicken pieces
	Pre-chopped fresh vegetables:	330g	Stir-fry in olive oil
	White cabbage	27%*	
	Red pepper /capsicum	20%*	
	Leek	20%*	
	French/green beans	20%*	
	Bean sprouts	13%*	
	Straight to wok Noodles	150g	Stir-fry in olive oil
	Olive oil	20ml	For the vegetables

Notes: All ingredients are fresh unless indicated and have not been frozen and defrosted. No seasoning was used. The olive oil was 95% refined and 5% extra virgin*. The prefix "pre" shows ingredient purchased in the described form. Symbol * denotes data taken from packaging.

Figure 2: Scripted cooking events at TNO

3 Performance Testing

The performance of domestic cooker hoods has typically been quantified using long-established methods that test air flow, energy demand, and noise; for example IEC Standard 61591 and ANSI/AMCA 210- ANSI/ASHRAE 51. These use standardized equipment to assess performance and have led to certification programs for airflows specified by many building codes, standards and regulations. Recently, a standardized test method (ASTM E3087) [1,6] has been developed to measure a more fundamental aspect of performance, the cooker hood *capture efficiency* (CE). A CE is defined as the proportion of contaminants emitted by cooking that are captured by the cooker hood before they mix with indoor air. Currently the test method only applies to emissions from cooktops, and not from ovens. Also, the test method is limited to wall-mounted hoods and does not consider island or downdraft variants, although they are being developed [5,22].

It is expected that this new CE test method will be integrated into a joint ASTM/IEC standard so that products do not require different tests for different markets. The ASTM test method uses standardized heat sources and experimental apparatus, and a tracer gas to track the fraction of the hot plume above a cooktop captured by the cooker hood; see Figure 3. This standardized approach allows the CEs of any two cooker hoods to be compared directly.

The exhaust flow of a range hood can be high when compared to regular ventilation flows, but the resulting air velocity under the hood is of the same order, or less, than air velocities due to movement, cross ventilation, or thermal sources. Therefore, the CE of a hood in an individual kitchen will depend on the geometry of the kitchen, the mode of installation (the height of the hood above the cooktop and the presence of adjacent cupboards), the type of meal being cooked (browning meat or steaming vegetables) [11], the movement of people near the cooktop [10], open windows, and many other variables. To minimize the impacts of these extraneous influences, a cooker hood with a higher airflow rate should be used.

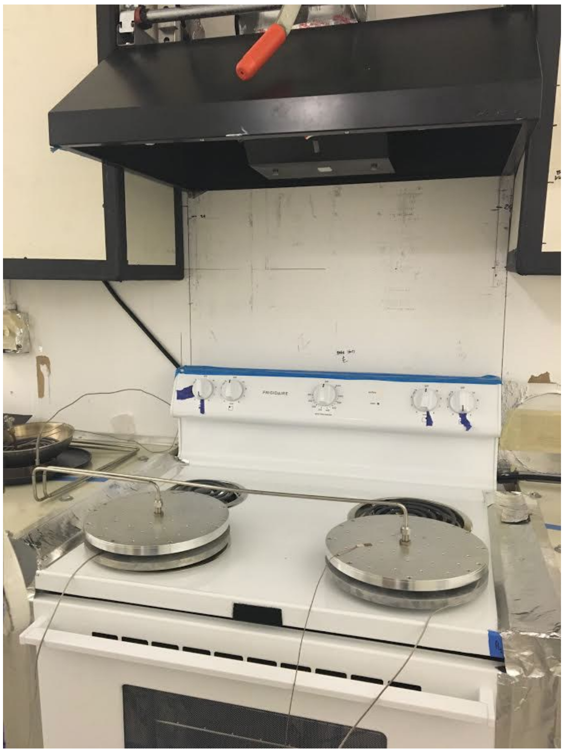


Figure 3: Apparatus for tracer gas CE testing

Unacceptable noise is a commonly reported issue for range hood operation [16, 18]. Hoods are rarely operated at the airflow rates required for good CE because they are too noisy. Some ratings include noise [17] but these measurements are often at lower speeds and at unrealistically low-pressure differences. Future performance testing should consider measuring noise at the same airflow rate used to determine a CE and airflow rating. In addition, improved aerodynamic designs, sound absorbing ducts and a greater use of remote fans could be used to reduce noise.

4 Progress on standards

ASTM E3087 has been used by third parties (primarily Texas A&M and a few US manufacturers) and the industry is gaining experience in performing the tests. Feedback will be used to update the ASTM test method. Possible changes include:

- Having tighter specifications for surface temperatures of heating elements
- Having more detailed requirements hoods mounting – e.g., it must be flush with rear wall
- Using multiple test points to measure room tracer gas concentrations
- Adding procedures for island and downdraft hoods
- Being more specific about emitter/burner height above the countertop.

The US national ventilation standard (ASHRAE 62.2) committee is working on language to include a CE requirement for kitchen ventilation. In California, there are proposals to require a minimum CE and distinguish between electric and gas cooktops, as well as scaling performance by house dimensions to account for dilution effects, as shown in Table 1. The CEs are those required to keep NO_2 and PM below exposure limits. A higher CE is required to control NO_2, therefore the gas cooktop has higher CE (and airflow) requirements [4].

Table 1: Proposed 2022 California Energy Code Requirements for Cooker Hood Capture Efficiency

Dwelling Unit Floor Area (m^2)	Hood over Electric Cooktop	Hood Over Gas Cooktop
<150	50% CE or 52 L/s	70% CE or 85 L/s
100-150	50% CE or 52 L/s	80% CE or 118 L/s
75-100	55% CE or 60 L/s	85% CE or 132 L/s
<75	65% CE or 75 L/s	85% CE or 132 L/s

In England [26], building regulations prescribe intermittent kitchen ventilation rates of 30 l/s through a cooker hood or 60 l/s elsewhere, or a continuous ventilation rate of 13 l/s by any means. In new dwellings these requirements are obligatory, whereas it is only necessary to maintain existing ventilation systems when refurbishing the kitchen in existing dwellings. A modelling study [26] predicts that 98% of English homes are too airtight to dilute PM_{25} emitted by cooking solely by infiltration so that daily mean concentrations in kitchens are below the WHO guideline value. Using this value as a benchmark of acceptability, it then estimates that current range hood ventilation rates are too low in 88% of English houses when used only during cooking. But, this reduces to 54% when occupants continue to ventilate for 10 minutes after cooking finishes.

5 Progress on technology

A key aspect of kitchen ventilation is that the exhaust systems must be turned on to be effective. Almost all cooker hoods have manual controls operated by the occupants of a home. Studies have found that occupants often do not operate their cooker hood. A study in California [2] found that cooker hoods were used for 36% of cooking events in houses and 28% in apartments. A Canadian study [3] found only 12% of homes used the cooker hood. However, studies in Korea [19] showed much higher range hood use, possibly due to higher-emitting events, such as stir-frying. Cooker hoods would be more effective if their operation was automated so that they turn on wherever there is a cooking event. Existing automated products in the US focus on detecting excessive heat events (above 60°C inside the hood) and are not suitable for automating general cooking. Products are currently being developed in the US that use a range of technologies to sense cooking events. The challenge is to have automated controls that are sensitive enough to operate for low or moderate cooking processes, but do not activate the cooker hood when there is no cooking taking place. Recent testing at LBNL used scripted cooking events, to evaluate automatic operation; see Figure 4. Low noise levels are important for user acceptance [16,18].

Recirculating hoods have been developed with particle filtration, but they do not address gaseous contaminants or water vapour (although there is ongoing development to remove VOCs using carbon-based filtration and catalysts). An aging test [23] performed on a typical commercial carbon filter in a recirculation hood, simulating 19 days of cooking (20 minutes/day 5 kW), showed an initial NO_2 reduction of 56% that reduced to only 19% after 19 days. Air purifier placement with carbon filters resulted in an immediate decrease in the NO_2 concentration in the kitchen and bedroom, but after 3 months, a significant reduction was only seen in the kitchen [21]. The same study shows that replacing the gas stove with an electric stove gave the greatest and most long lasting reduction in NO_2 concentrations.

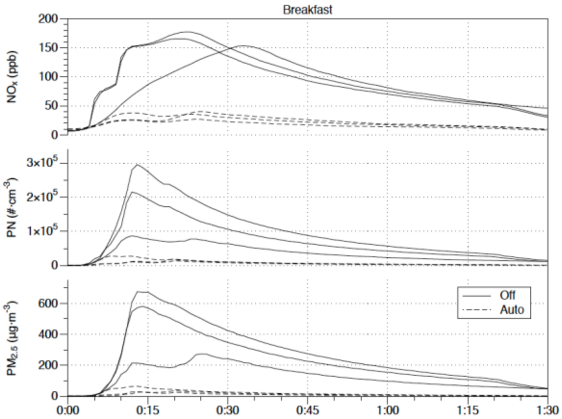


Figure 4: Contaminant Concentrations in Kitchen with and without automatic hood operation.

In airtight homes there may be issues with home depressurization with the large airflow associated with cooker hoods – particularly if natural draft combustion devices, such as boilers, furnaces and water heaters, are located inside the building envelope. In these homes it may be necessary to provide make up air for the kitchen exhaust. Products are commercially available for providing make up air for cooker hoods but they are expensive and can be difficult to install and require maintenance.

A key aspect of future hood development will be to achieve better CE at lower airflow rates and to reduce their noise, which is a key factor in user acceptance and likelihood of operation.

6 Best Practices

- Locate the cooker against an outside wall and mount the hood against the same wall and between cabinets to improve flow direction. - Use the shortest possible ducts, and avoid flexi-duct
- Use wide ducts to reduce the air velocity to 2-3 m/s
- Use noise absorbing ducts, reduce the amount of duct curves
- Use a hood that covers all the hobs/burners
- Use a hood that exhausts outside
- Use a hood with a low pressure drop
- Mount the hood as close to the cooktop as is practical
- Cook on back hobs/burners

- Use the fan on its highest setting when cooking and continue to use it for 10 minutes afterwards [26]
- Choose the quietest hood possible that doesn't compromise its CE
- Consider using the hood, at least on low speed, for general kitchen ventilation, when using other appliances such as toasters, or place the toaster under the hood.
- Use induction rather than gas cooktops and electric rather than gas ovens.
- In very tight homes (<1 ACH50) supply make up air to the kitchen or home.
- If a cooker hood is not present, use a wall mounted extractor fan on its highest setting whenever cooking and for a sufficiently long time afterwards (equivalent to about 3 times the volume of the room)
- If a fan is not present, open windows and doors to ventilate. Keep trickle ventilators open at all times.

An example of a *best practice* range hood installation is in a NeroZero dwelling [20]; see Figure 5. It has a sound pressure level of 23 dB(A) with an exhaust airflow rate of 300 m^3/h (83 l/s). This was done by using a range hood with a low pressure drop combined with noise absorbing ducts with a diameter of 180 mm. This concept is suitable for very airtight energy efficient dwellings when make-up air is supplied and the cooking heat can be recovered by the ventilation system heat exchanger.

Figure 5: Range hood with reduced pressure drop and 180 mm diameter noise reducing duct

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