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INDOOR AIR QUALITY: RESIDENTIAL COOKING EXPOSURES

FINAL REPORT

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ABSTRACT

A study was performed in a Test House in California to collect data that will provide a better understanding of the impact of residential cooking activities on exposure to particles and gaseous Toxic Air Contaminants. Particulate matter (PM), carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO_2), polycyclic aromatic hydrocarbons (PAHs), elements, and aldehydes were measured. Thirty-two tests were performed to measure the impact of cooking during typical cooking activities with gas and electric ranges and to evaluate variables that might impact emissions. The study also included tests of worst-case cooking conditions and of potential exposure reduction methods. The study demonstrated that cooking can produce high concentrations of particles and gases. $PM_{2.5}$ concentrations were over 1000 µg/m^3 during stovetop stir-frying, frying of tortillas in oil on the range top burner, and baking lasagna in the gas oven. PM_{10} concentrations measured in the kitchen, living room, and bedroom ranged from below the detection limit to 3660 µg/m^3 in the 32 tests. Combustion pollutants were elevated in the house primarily during use of the gas range. CO concentrations during cooking periods were generally less than 4 ppm, but exceeded 9 ppm during preparation of a full meal and during oven cleaning. NO_2 concentrations were greater than 50 ppb during some tests with the gas range and averaged 400 ppb during the 5-hr oven cleaning test, exceeding the ARB Indoor Air Quality (IAQ) Guideline of 250 ppb over one hour, and representing a significant source of exposure. Formaldehyde concentrations exceeded the ARB action level of 0.1 ppm (124 µg/m^3) during oven cleaning and broiling of fish. Several PAH compounds were found in the fresh cooking oils used in the study, but the concentrations were low in the house during cooking. The data, however, suggest that additional study is warranted to fully evaluate the impact of cooking on PAH exposure. The results of the study demonstrated the significance of cooking as a source of exposure to particles and Toxic Air Contaminants. Because of the high variability of the emissions during cooking, it was difficult, however, to quantitatively determine the impact of variables such as food type, cooking method, pan material, or the impact of simple exposure reduction methods.

EXECUTIVE SUMMARY

Background

Cooking has been identified as a potentially significant source of indoor air pollution and personal exposure to Toxic Air Contaminants. Results of a number of studies suggest that cooking may be a major source of exposure to particulate matter (PM), combustion pollutants, polycyclic aromatic hydrocarbons (PAHs), and other organic compounds. Epidemiological studies have found significant associations between increased respiratory symptoms and the presence of, or cooking with, a gas range. Despite the recognition that cooking may be an important source of air contaminants in residential dwellings, emissions from cooking and the resultant exposures have not been well characterized.

The current study was performed for the California Air Resources Board (ARB) to gain a better understanding of the impact of cooking on indoor air concentrations and personal exposures to air contaminants generated by cooking in residences. This study represents the first large-scale study of cooking emissions and the resultant exposures in a residential setting under semi-controlled conditions. The study included thirty-two cooking tests with a variety of cooking methods and foods. It addressed various factors that may impact emissions from cooking and evaluated simple exposure reduction methods.

Methods

To meet the study objectives, a test house was rented in Rohnert Park, California. The house was a small, single-story ranch style home constructed in the 1970s. The small size of the house (less than 1000 ft^2) and the layout of the rooms, consisting of a kitchen, adjacent living room, and three bedrooms, resulted in good air mixing in the house even though the house air handler was not operated during testing. The house had an attached garage where a laboratory was set up. The test house was instrumented for the following measurements:

- CO, NO, and NO_2 with continuous pollutant monitors,
- Real-time PM concentrations and size distributions (12 size fractions from 0.04 to 8.4 μm, aerodynamic mean diameter) with an electrical low pressure impactor (ELPI) that recorded data continuously,
- $PM_{2.5}$ and PM_{10} mass, collected on Teflon® filters with size selective inlets,
- Air exchange rates,
- Temperature and relative humidity (RH) indoors and outdoors,
- Range top burner and oven temperatures,
- Gas or electric use during cooking, and
- PAHs, elements, and aldehydes, in a subset of tests.

Following a pre-test and refinement of the study design and test protocols, a main study was performed that consisted of 32 cooking tests at the test house. The tests involved cooking with an electric range, gas range, and microwave oven. The electric range was used for seven cooking tests. These same seven cooking activities were performed with the gas range for comparison.

The microwave was used in three tests to compare emissions with the gas and electric ranges. All other tests were performed with the gas range.

Realistic cooking activities were performed during the study. They involved cooking activities such as stovetop stir-frying on the range top burner, frying tortillas in oil, broiling fish in the oven, and baking a pre-packaged frozen lasagna in the oven. The amount of food cooked was larger than would be typical in a residential setting, and the duration of cooking was generally longer than typical, in order to obtain sufficient pollutant mass for analysis.

Results

Average $PM_{2.5}$ mass concentrations in the kitchen, living room, and bedroom ranged from below the method detection limit (3 µg/m^3) to 3,880 µg/m^3 during 32 cooking tests. PM_{10} concentrations ranged from below the method detection limit to 3660 µg/m^3. Indoor concentrations during cooking were substantially higher than the outdoor concentrations, which ranged up to 13.6 µg/m^3 during the study. The highest concentrations occurred during operation of the self-cleaning feature of an intentionally dirtied gas oven. During routine cooking, the concentrations of $PM_{2.5}$ were over 1000 µg/m^3 during stovetop stir-frying, frying of tortillas in oil on the range top burner, and baking lasagna in the gas oven. Continuous, real-time PM measurements with an electrical low-pressure impactor (ELPI) showed that the particles emitted during cooking were primarily in the size fractions of less than 1 µm.

The median and average $PM_{2.5}$ concentrations during the six standard (typical) cooking tests, which ranged from approximately 1.5 to 5 hours in duration, exceeded the federal National Ambient Air Quality Standard (NAAQS) level of 65 µg/m^3 (24 hour average). The median and average PM_{10} concentrations would be expected, under typical indoor conditions, to cause indoor levels to exceed the State PM_{10} Ambient Air Quality Standard and ARB IAQ Guideline of 50 µg/m^3 over 24 hours. The data indicated that cooking can be a significant source of exposure to PM.

Element concentrations measured in indoor air PM_{10} samples during the cooking tests exceeded outdoor concentrations for most elements. Of potential importance were elevated concentrations of chromium, titanium, nickel, and zinc during the oven self-cleaning tests. Due to the short test periods and low mass levels in the samples, element measurements were below the method detection limit in many samples.

As expected, combustion pollutants were elevated in the house primarily during use of the gas range. Average CO concentrations during cooking periods were generally less than 4 ppm, although concentrations higher than the ARB IAQ Guideline of 9 ppm (8 hr.) were measured during preparation of a full meal and during oven cleaning. NO_2 concentrations were greater than 50 ppb during four of six standard cooking tests with the gas range and averaged over 400 ppb in all three rooms during the 5-hr oven cleaning test, exceeding the ARB IAQ Guideline of 250 ppb (1 hour).

A number of PAHs, which ARB has identified as Toxic Air Contaminants under the grouping of Polycyclic Organic Matter, were identified by gas chromatography/mass spectrometry analyses of bulk samples of cooking oils used in the study. During cooking tests with these oils, PAHs were measured in air samples collected in the kitchen. However, there was not a clear relationship between the presence of PAHs in the oils and the concentrations of the PAHs in the air samples. The concentrations of PAHs in the air samples collected in the kitchen during the cooking tests were within the range of concentrations measured in other indoor air studies. The indoor concentrations were generally higher than concurrent outdoor concentrations indicating that cooking was a source of PAHs. The data suggest that additional testing and analyses are warranted to more fully evaluate the impact of cooking on exposure to PAHs.

Formaldehyde and acetaldehyde, Toxic Air Contaminants identified by the ARB, were present in air samples collected during oven cleaning, broiling fish, and oven pork roast tests. During the 5-hr oven cleaning tests, the formaldehyde concentrations of 417 and 224 $\mu g/m^3$ with the gas and electric ranges, respectively, substantially exceeded the Acute Reference Exposure Level (REL) of 94 $\mu g/m^3$ (1 hour) (OEHHA, 1999) and the Action Level of 0.10 ppm (124 $\mu g/m^3$) from the ARB IAQ Guideline (CARB, 1991). During the broiling fish test, the formaldehyde concentration of 129 $\mu g/m^3$ also exceeded the action level. Acetaldehyde concentrations of 434 and 92 $\mu g/m^3$ were measured during oven cleaning and fish broiling tests with the gas range. Although the aldehyde measurements were limited in scope, they indicated that cooking might have a significant impact on aldehyde exposures.

Oven cleaning resulted in the highest concentrations of the measured air contaminants in the house during the study. Of the six standard cooking tests performed with both the gas and electric range, the highest emissions of PM occurred during frying of tortillas in oil on the electric range and baking a frozen lasagna in the gas oven. Broiling fish also produced high PM emissions.

In worst-case tests that involved realistic activities such as heating cooking oils too hot or slightly burning food, indoor air concentrations and emission rates were generally higher than in the standard tests. With the exception of the oven-cleaning tests, the highest PM concentrations were measured during the worst-case stovetop stir-frying test.

The impact of variables such as type of cooking method, type of food, or pan material could not be determined quantitatively in this study. The concentrations of the air contaminants measured in the rooms and the emission rates calculated with the mass balance model were too variable to determine the significance of differences between different cooking activities. Adjusting the emission rates for the food mass lost or the energy used during cooking did not change the observed trends.

Tests with the microwave demonstrated that emissions of PM and combustion pollutants were lowest with this cooking method. It was the most effective exposure reduction method evaluated in the study. Tests with the range hood exhaust and range hood side shields resulted in lower concentrations of some of the air contaminants, but there was not a dramatic reduction in indoor air pollutant concentrations.

Conclusions

The data collected in the study successfully addressed the project objectives. The results provide a better understanding of the impact of cooking on indoor air pollutant concentrations and exposure. The data indicated that cooking is a significant, although highly variable, source of PM indoors. Exposure to PM due to cooking may be substantial for many individuals, depending on the amount of cooking that is done and the duration of time spent in the home following cooking. With a gas range, exposures to NO_2 and CO are increased substantially. Exposure to formaldehyde can be significant during some cooking activities using either gas or electric ovens.

Oven cleaning was identified as the largest source of emissions of PM, CO, NO, NO_2, formaldehyde, and acetaldehyde. Data from the oven cleaning tests suggest that guidance should be developed to help reduce exposure to air contaminants during operation of the self-cleaning feature of gas and electric ovens.

The results of the study cannot be used to quantitatively assess the impact of different types of cooking methods, different foods, or other parameters related to cooking methods and utensils due to the high variability in the emissions. To evaluate the impact of these parameters, a much larger number of tests would need to be performed. These tests could be performed under highly controlled conditions in environment test chambers or in field studies under realistic cooking conditions.

The results of the study suggest that additional research is warranted to more fully characterize the impact of cooking on exposure to Toxic Air Contaminants, such as PAHs and aldehydes and to evaluate exposure reduction techniques under realistic conditions in residences.