AIR QUALITY MEASUREMENTS IN A MODEL KITCHEN USING GAS AND ELECTRIC STOVES

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ABSTRACT

Epidemiological studies suggest that cooking with gas leads to an increase of air pollutants and may enhance symptoms of respiratory diseases. However, little experimental data are available concerning the emission of pollutants due to different cooking processes. The goal of this study was to investigate the influence of cooking under standardized conditions on the indoor air quality. A model kitchen was built and three different gas stoves and one electric stove were included in the study. Two different menus were prepared with different settings of the ventilation rate of the exhaust. Online measurements of NO, NO_2, CO, particles, polyaromatic hydrocarbons and climatic factors were performed on the side of the stoves. The results showed large differences between different gas stoves with respect to emission of gaseous pollutants. Particle concentrations depended strongly on the menu cooked independent of the stove used. An adequate exhaust hood and ventilation rate are required in order to reduce the air pollutants, in particular the fine particles, to tolerable concentrations.

KEYWORDS: Gas appliances, kitchen exhaust hood, carbon monoxide, nitrogen oxides, particulate matter, ventilation

INTRODUCTION

In Switzerland, out of 2,5 million households some 20% are supplied with natural gas, mainly for cooking. Epidemiological studies suggested that cooking with gas leads to an increase of air pollutants (mainly NO, NO_2 and CO) and may enhance symptoms of lung diseases. However, in the numerous studies conducted during the past both positive and negative associations between symptoms and pollutants levels have been reported [1]. Most positive studies indicate, that effects are small and difficult to detect. Many studies concentrated on children which are believed to be more susceptible to effects of indoor air pollution than adults [2]. Since recent studies showed that peak concentrations may be more important for health effects than long-term concentration averages [2] the persons doing the cooking at the stoves are primarily exposed and at risk. This was confirmed in a study where associations were found between the use of gas stoves and lung function decrements and increased respiratory symptoms for young women but not for men living in the same homes [3]. Different (mainly epidemiological) studies reported higher NO_2 and particle concentrations in kitchens and living rooms of homes with gas-cooking compared to the homes with electrical stoves [4-7]. Studies with focus on the kind of stoves used showed that pilot lights are a main contributor for increased NO_2-concentrations and that large differences could be found between kitchens with gas ranges and ovens and those with gas ranges only [8, 9].

However, data about the amount of pollutants emitted during cooking of different foods under different ventilation conditions are missing. The goal of this study was to investigate the influence of cooking under well standardized conditions on the air pollution concentrations inside a model kitchen.

METHODS

For the experiments, a model kitchen was designed and built in the laboratory. The kitchen was of a wooden construction (3 x 4 m, 2.3 m high) and equipped with standard appliances. Three gas stoves of different design and one electric stove were included in the study. The different stoves were installed underneath a kitchen exhaust hood with variable settings of the ventilation rate (90, 155, 200 and 260 m^3/h). The main experiment consisted in the preparation of two different common menus (chicken curry with rice or a potato pancake (Rösti) with fried egg) with each of the stoves and with the four different ventilation levels in operation. All the experiments were conducted in duplicates.

The samples for the measurements were taken nose high on the right side of the stove. The investigation included online gas measurements for NO, NO_2 and CO (Monitor Labs, APMA-300E), different particle measurements (Grimm Dust Monitor for counts per liter; PM_{10}) and polyaromatic hydrocarbons (PAH) measurements, climatic factors (temperature, relative humidity, wind velocity) and passive samplers for NO_2 and formaldehyde. The consumption of gas and electricity were also measured concomitantly.

RESULTS

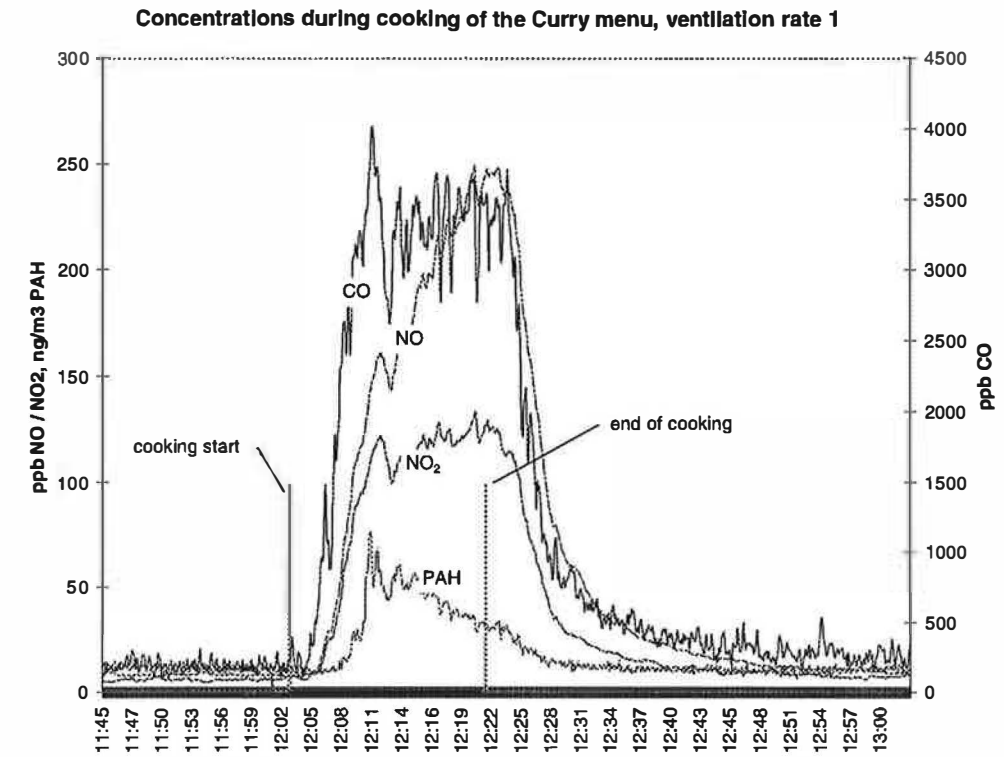
Measured pollutants and influence of the different menus
The menus "Curry" and "Rösti" were cooked with standardized procedures on the three gas stoves and on the electrical stove with each of the four different ventilation rates in operation twice. Cooking of the menus on the gas stoves increased the concentrations of CO, NO and NO_2 (Figure 1a). The amount emitted pollutants depended on the amount of gas burned during each experiment, the number of burners in use and on the type of stove.

During all the cooking experiments, i.e. also upon using the electric stove, particle counts increased (Figure 1b). Especially in the menu Curry, when meat was fried in the pan the particles reached extremely high concentrations, 10-20 times higher than with the Rösti menu. During the frying of the potato chunks (Rösti) in the pan the temperatures were lower than in the Curry menu and probably less oil or water aerosols were generated.

The PAH-concentrations were also dependent on the menu cooked. They were mainly elevated during frying meat. In the experiments with the Curry menu an increase up to 50 ng/m^3 was seen in one case with ventilation rate 1 (Figure 1a), but usually only slight increases occurred (average increase during the whole cooking period of about 5 ng/m^3). Hardly any change in PAH-concentration was observed during the preparation of the Rösti menu and in most cases where the oven was used.

Temperature and relative humidity inside the kitchen raised depending on the amount of gas burned (different for the two menus). Rice was cooked with the Curry menu and the steam of the boiling water increased the relative humidity by a few percents depending on the actual ventilation rate setting (data not shown). At the end of the cooking all concentrations dropped rapidly back to baseline concentrations while the exhaust was still in operation (Figure 1).

a.



b.

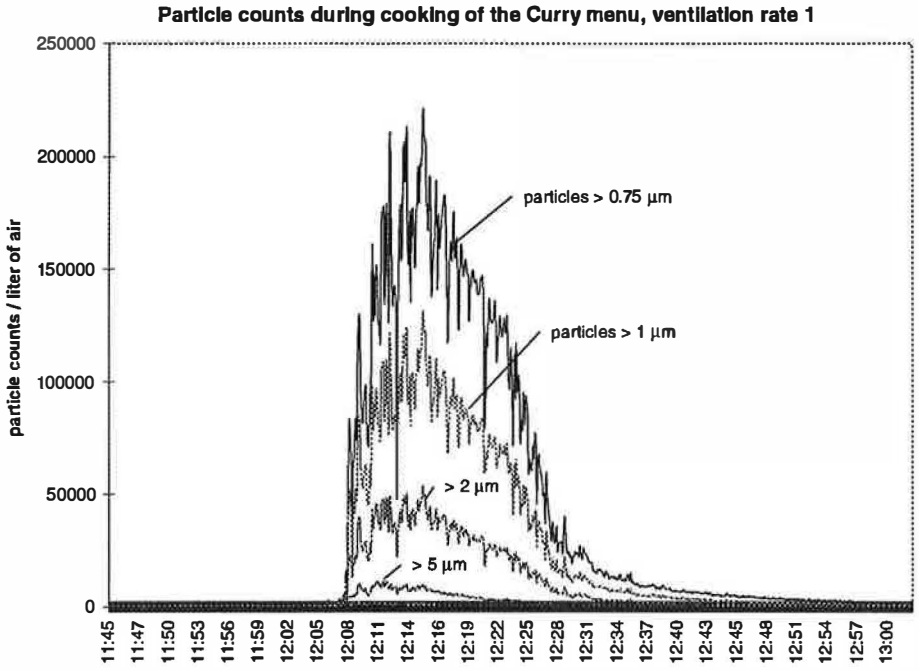


Figure 1. Concentrations of CO, NO, NO_2 and PAH (a) and particles (b) during cooking of the Curry menu on gas stove 1 and with ventilation rate 1 in operation. A total of 80 liters of gas was burned.

Differences between the stoves

Experiments without and with a pan but no cooking except water on top of the burners and the experiments with the cooking of the two menus showed that large differences between the four different stoves and the measured concentrations of pollutants occurred (Figure 2). While only the cooking of the menus with gas stoves leads to increased concentrations of NO, NO_2 and CO in the kitchen air, the highest particle concentrations were measured during cooking on the electrical stove. For comparison of the four stoves used in the experiment of Figure 2, the same menu was cooked to the same extent as closely as possible.

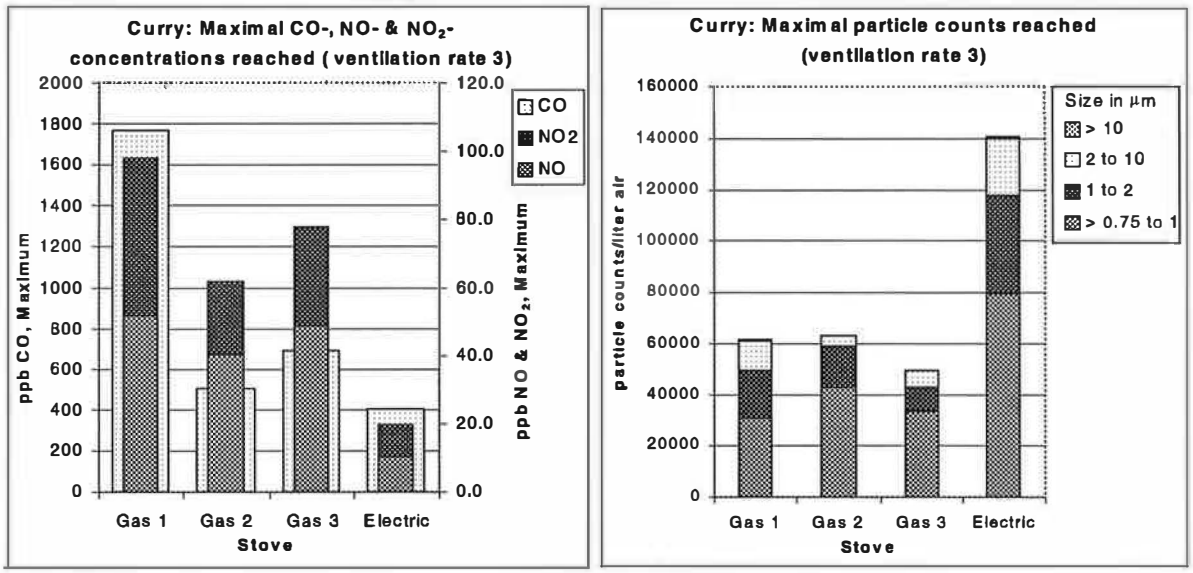


Figure 2. Maximal concentrations of NO, NO_2 and CO as well as particle counts during the cooking of the Curry menu with the three different gas stoves and the electrical stove. (Baseline concentrations: 130-280 ppb CO; 9-11 ppb NO; 5-8 ppb NO_2 and 500-4000 particles > 0.75 • m). The same Curry menu was cooked on the 4 different stoves under standardized conditions.

Influence of the use of a gas oven

If no kitchen exhaust was in operation the concentrations of CO, NO and NO_2 increased steadily during the use of a gas oven. In the experiments with an oven temperature of 200°C during 50 minutes the maximal concentrations were 2-20 ppm CO, 750-2000 ppb NO and 350-700 ppb NO_2, depending on the type of oven in use. With ventilation rate 1 in operation the concentrations only reached 20-30 % of the maximal concentrations without ventilation. With the electrical oven there was no increase in NO- and NO_2-concentrations, but CO-concentrations slightly increased. Except for a raise in temperature and relative humidity no significant effects on particle concentrations or other pollutants were seen during the experiments with the gas or electrical ovens.

Effect of ventilation

Figure 3 shows the effect of the ventilation rate setting of the exhaust hood on the pollutant concentrations. Setting 2 (155 m^3/h) reduces these concentrations significantly compared to setting 1 (90 m^3/h). A further increase in the ventilation rate (settings 3 and 4) does not necessarily lead to a further improvement of the air quality.

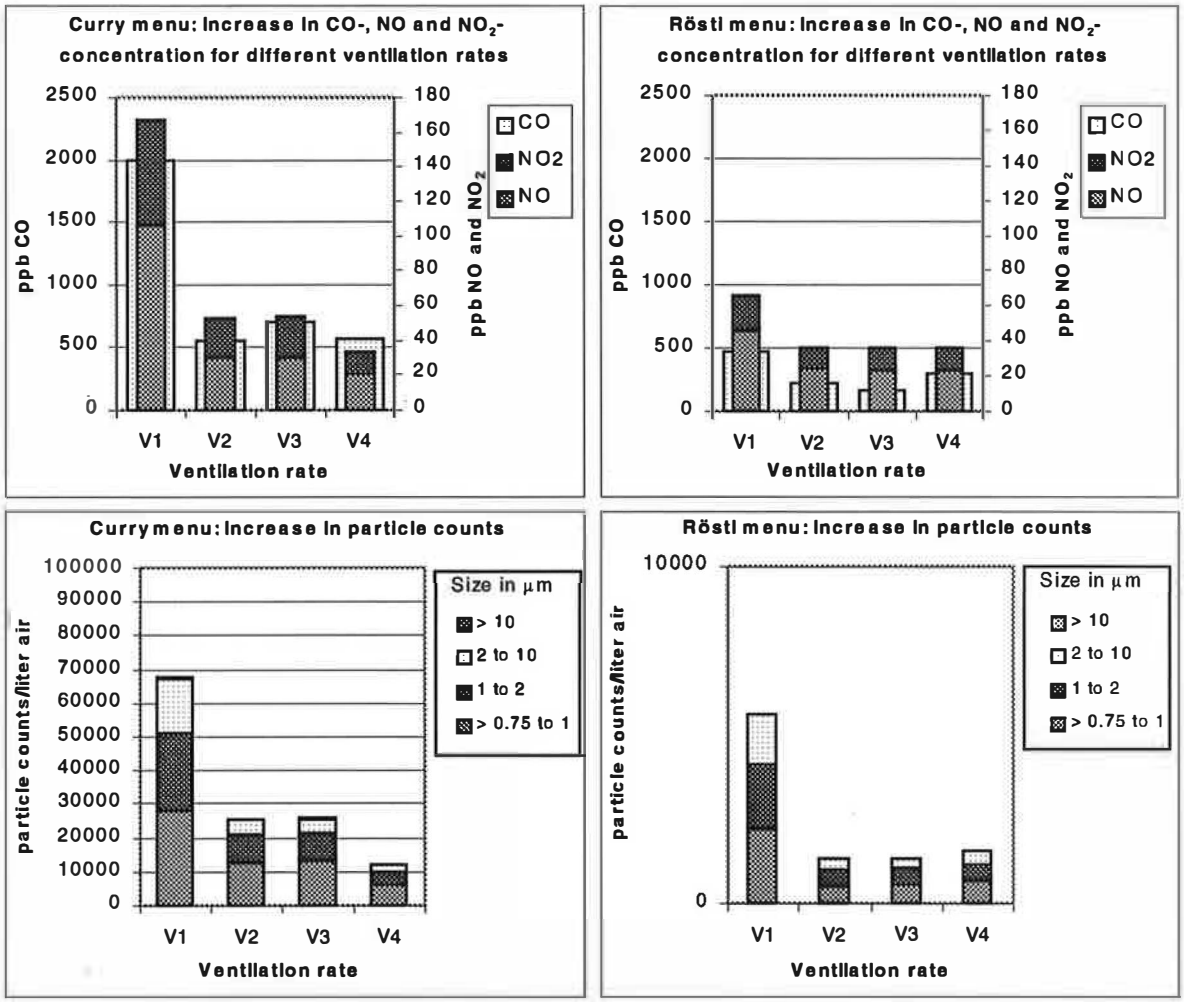


Figure 3. Average increase in CO-, NO and NO_2-concentrations (ppb) and average increase in particle counts per liter of air during cooking of the two menus Curry and Rösti with gas stove 1 under different ventilation settings (V1 to V4).

The location of the gas burner used for the cooking was important for the ventilation efficiency. Using a gas burner in the front caused a higher increase in pollution concentrations than a burner in the back. The evaluation of the ventilation flow showed that the exhaust was much more effective in the back half (75% of the total air flow) than in the front row of the stove.

Since in many kitchens the exhaust ventilator is integrated in a row of cupboards on the wall experiments were conducted to simulate this situation. Two pieces of cardboard (30 cm high) were tightly attached along the side of the kitchen exhaust hood. The experiments with the menus showed that this modification increased the efficiency of pollutant removal enormously and reduced the pollutant concentrations by about 50 % under the same ventilation rate setting (data not shown).

DISCUSSION

Our results showed very short concentration peaks for NO, NO_2 and CO during the cooking of a menu, but with large differences using different gas stoves. Hourly means of these emissions were much below WHO guidelines [10]. However, particle concentrations reached during the cooking were high and depended strongly on the menu cooked and on the ventilation performance. They tended to be higher with the electric than with the gas stoves, probably because of the slower temperature adjustments with the electrical heating than using a gas burner.

The design of the kitchen exhaust proved to be poor and only slight improvements of the pollution situation in the kitchen were reached with increased ventilation rates. Simple improvements of the design of the exhaust hood (small covers on the side) allowed to reduce pollutant concentrations in the ambient air during cooking to tolerable levels.

The main contribution of NO, NO_2 and CO comes from the use of gas ovens. Here it is important that adequate ventilation is provided (better instructions of the users and/or technical measures).

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