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Characterization particulate matter from several Chinese cooking dishes and implications in health effects

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ABSTRACT

Cooking fume produced by oil and food at a high temperature releases large amount of fine particulate matter (PM) which have a potential hazard to human health. This chamber study investigated particle emission characteristics originated from using four types of oil (soybean oil, olive oil, peanut oil and lard) and different kinds of food materials (meat and vegetable). The corresponding emission factors (EFs) of number, mass, surface area and volume for particles were discussed. Temporal variation of size-fractionated particle concentration showed that olive oil produced the highest number PM concentration for the entire cooking process. Multiple path particle dosimetry (MPPD) model was performed to predict deposition in the human respiratory tract. Results showed that the pulmonary airway deposition fraction was the largest. It was also found that particles produced from olive oil led to the highest deposition. We strongly recommend minimizing the moisture content of ingredients before cooking and giving priority to the use of peanut oil instead of olive oil to reduce human exposure to PM.

Introduction

China has the largest population of more than 1.3 billion, and cooking is considered as the most common daily activity for Chinese families. Chinese cooking includes a number of cooking styles, such as frying, boiling, steaming, grilling, *etc.*, and generally requires a large amount of oil, with an average consumption of 44 g of oil per adult per day. Prior to adding the food ingredients, oil needs to be heated for a certain amount of time and reach a high temperature. The high temperature helps the cooking smoke fume produced from the heated oil nucleate into ultrafine particles (Lai and Ho, 2008). Drastic chemical changes occur during cooking process, and they can be classified mainly into the following three categories: (1) thermal oxidation or decomposition of food and oil; (2) the Maillard reaction of carbohydrates, protein, amino acids and chemical composition; (3) secondary reaction between the reaction intermediate or final products.

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Cooking produced emissions are considered to be very important pollutant sources for indoor and outdoor air pollution. Cooking emissions aggravate indoor air pollution and are harmful to human health. It has been reported that cooking activity could be one of the major particulate matter (PM) sources indoors (Cass, 1998; See and Balasubramanian, 2006; Buonanno et al., 2009, 2010; Torkmahalleh et al., 2012) that approximately contributes nearly 30% to the indoor particle concentration in the size range of 0.5 to 5 μm (Liao et al., 2006). It can also have a very important role for the outdoor air quality, especially in the urban environment (He et al., 2004). In addition, ultrafine particles emitted by cooking activity accounted for more than 90% of the total particle number indoors (He et al., 2004). Hussein et al. (2006) found that cooking could elevate the indoor submicrometer particle number concentration levels by more than five times, while fine particulate matter ($PM_{2.5}$) concentration could be up to 90 times higher compared to normal levels. The number concentration of PM coming from cooking activities could reach up to the value of 1.8×10^6 particles/cm^3. Different cooking styles, such as frying, boiling, steaming and grilling, also greatly affected the emission of particles. The particles in the fume could deposit into the lungs, leading to the adverse health effects on both respiratory and cardiovascular system, including decreased lung function, asthma, myocardial infarction, all-cause mortality or cancer (Gold et al., 1999; Koo and Ho, 1996; Lei et al., 1996; Samet et al., 2000; Simkhovich et al., 2008; Wang et al., 1996; Zhong et al., 1999).

Cooking fume contains more than 200 types of chemical compounds including polycyclic aromatic hydrocarbons (PAHs), heterocyclic amines, aldehydes, ketones and other harmful gasses (Liao et al., 2006). The fume produced by cooking contains a number of potentially toxic compounds, such as PAHs, heterocyclic amines and unsaturated aldehydes (He et al., 2004). PAHs are found to be genotoxic and carcinogenic to humans (Franco et al., 2008). The fume generated by cooking also contains black carbon which has negative impact on the respiratory system (Suglia et al., 2008) and increased risk of emergency myocardial infarction hospitalization (Zanobetti and Schwartz, 2006). McCracken et al. (2010) reported that an increase of annual black carbon (BC) of 250 ng/m^3 was associated with a 7.6% decrease in leukocyte telomere length (McCracken et al., 2010). In order to get a better understanding of the relationship between the air pollution and cooking activities, different cooking styles of Chinese cuisine that are Hunan Cooking, Cantonese Cooking (He et al., 2004), Sichuan Cooking and Dongbei Cooking (Zhao et al., 2007) were investigated. Organic compounds accounted for more than 50% of the $PM_{2.5}$ in the report of He et al. (2004). The two studies reported that organic compounds account for 26.1% and 5%–10% of bulk organic particle mass or particle organic matter, respectively. Fatty acids were constituting 73%–85% of the quantified organic material in the research of Zhao et al. (2007), while diacids and steroids were found to be major organic compounds. The type of cooking ingredients was found to be an important factor for studying particle emissions. Some reports showed that cooking fat food produced more particles than cooking cabbage (Buonanno et al., 2009; Dennekamp et al., 2001). Hence, cooking process is capable of emitting different profiles of compounds, indicating the significance of various factors such as cooking processes, ingredients, and temperature as well as oil types.

Comparatively, a few studies focused on temporal variation of particles emitted from different oil and particle deposition in human respiratory tract. Considering potential hazards to human health during high-temperature cooking, it is of utter importance to explore emission characteristics using different oils and ingredients and simulate the deposition of particulate matter in the human respiratory tract. Therefore, this study aimed to investigate the particle properties generated from several typical Chinese dishes cooked by different oil types and food materials. The time-dependent particle number, mass and volume size distributions were characterized. On this basis, the size-fractionated particle deposition at various sections of respiratory system for human beings was assessed.

1. Methodologies

1.1. Samplings

The experiment was conducted in a laboratory, simulating a simple kitchen set up. The cooking activities were operated in a chamber with a fan installed in the chamber, rotating in the horizontal plane to allow proper mixing of the generated fumes with the air inside the chamber. The mixing intensity could also be adjusted through the fan speed. The efficiency of mixing was checked by measuring size distribution and the mass at different heights inside the chamber as well as at the same heights but different locations, which were *via* the holes around the chamber. The top of the chamber was sealed to prevent any possible leaks. The chamber was 2 m high with the diameter of 1 m.

The diagram of aerosol sampling system is just as Fig. 1. There were several holes, with the diameter less than 1 cm, set around the wall of the chamber, which were designed as sampling points. Black carbon (BC) concentration was monitored at the central sampling point (at the height equivalent to the half of its total height), which provided a stable concentration of BC due to a well-mixed fume. Particulate mass, particle number concentration and particle number size distribution were sampled just above the induction cooker. Air exchange rate (AER) was measured by flow rates of the pump, which were calibrated by the flow meter prior to sampling. AER was 2.41/hr with the three pumps working, and each pump was with a flow rate of 20 L/min.

1.2. Instrumentation and chemical analysis

Particulate size distribution was monitored using a Fast Mobility Particle Sizer (FMPS 3091, TSI, USA), which was capable of sampling particles in the range between 5.6 and 560 nm with the time resolution of 1 sec. The number, surface and volume concentrations can be obtained from the FMPS. DustTrak™ DRX Aerosol Monitor Model 8533 (TSI Incorporated, St. Paul, MN, USA) was applied for PM (PM_1, $PM_{2.5}$, PM_4, PM_{10}) monitoring. The sampling flow rate was 3 L/min, and the