Significant Production of Secondary Organic Aerosol from Emissions of Heated Cooking Oils

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⊖ Supporting Information

ABSTRACT: Cooking emissions have been identified as a major source of primary organic aerosol (POA) in urban environments. Cooking may also be a potential source of secondary organic aerosol (SOA) because of the abundant emissions of non-methane organic gases. We studied SOA formation from the photooxidation of emissions from seven vegetable oils heated at 200 °C under high-NO$_x$ conditions in a smog chamber. After the samples had been aged under an OH exposure of 1.0×10^{10} molecules cm^{-3} s, the SOA formation rate was generally 1 order of magnitude higher than the POA emission rate. We determined that alkanals, which are not traditional SOA precursors in chemical transport models, accounted for 5−34% of the observed SOA. The unexplained SOA may be attributed to the oxidation of primary semivolatile and intermediate-volatility organic compounds (SVOCs and IVOCs, respectively), which were estimated to contribute an additional 9−106% of the observed SOA assuming the volatility distribution of heated cooking oils is the same as that of vehicle exhaust. Our results suggest that cooking can potentially be an important source of SOA in urban areas and that there is a need to characterize both SVOCs and IVOCs emitted from cooking and their SOA yields.
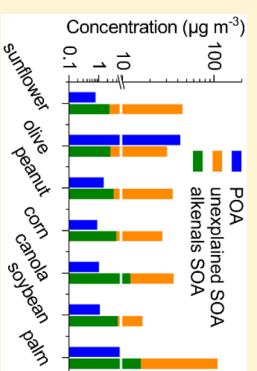
1. INTRODUCTION

Organic aerosol (OA), which comprises both primary and secondary organic aerosol (POA and SOA, respectively), has important impacts on air quality, climate, and human health.[1] SOA is formed via the oxidation of organic gases,[1] and the mass concentration of SOA often exceeds the amount of POA emitted directly from sources, even in urban areas.[2,3] However, our limited knowledge of sources and the mechanism of formation of SOA generally leads to large discrepancies between modeled and measured SOA concentrations[4−6] and therefore severely impedes our understanding of climate and health effects of SOA.

Cooking is an important source of POA in urban areas[7−13] and can potentially form SOA, as cooking emits SOA precursors such as alkanes ($<C_{10}$)[14−16] and primary semi-volatile and intermediate-volatility organic compounds (SVOCs and IVOCs, respectively; e.g., $\geq C_{13}$ n-alkanes, n-alkanals, and fatty acids).[16−18] Assuming that cooking emissions have volatility distributions of SVOCs and IVOCs and SOA yields that are the same as those of vehicle exhaust, Hayes et al.[19] showed via modeling that SVOCs and IVOCs from cooking emissions contributed 19−35% of the SOA mass in downtown Los Angeles. Recent laboratory studies have also demonstrated SOA formation from gas-phase emissions of heated cooking oils[20] and meat charbroiling.[21] However, the SOA formation

potential, relative POA and SOA contributions, and main SOA precursors related to cooking remain highly uncertain.

Frying with vegetable oils is a common cooking technique in numerous cultures,[22] and heated cooking oils can produce large amounts of particles[23,24] and organic gases.[15,16] In this work, we investigate the formation of SOA from the photooxidation of emissions from heated cooking oils under high-NO$_x$ conditions in a smog chamber. The objectives of this study are to identify the main SOA precursors, estimate the SOA formation potential, and evaluate the relative contributions of emissions of heated cooking oil to POA and SOA.

2. MATERIALS AND METHODS

2.1. Smog Chamber Experiments. Photooxidation
experiments were performed on emissions from seven cooking oils, including sunflower, olive, peanut, corn, canola (rapeseed), soybean, and palm oils, in a 30 m³ indoor smog chamber at the Guangzhou Institute of Geochemistry, Chinese Academy of Sciences (GIG-CAS)[25−27] (Table 1; see more details in the Supporting Information); these cooking oil types constituted