Figure 2. Estimated contribution of 10 individual alkenals to observed SOA for each heated cooking oil. Contributions were determined at the end of each experiment. Circles and triangles represent the contributions applying the lowest and highest SOA yields, respectively, for each SOA precursor.

acids ($\geq C_{13}$) falling in the SVOC and IVOC range have been observed in emissions from cooking with seed oils[17] and meat charbroiling.[18] By assuming that the volatility distribution of heated cooking oils was similar to that of diesel exhaust[54] and that the concentrations of IVOCs were 1.5 times the total mass of POA plus SVOCs[5,54] (see details in the Supporting Information), we estimated that SVOCs and IVOCs contributed 9−106% of the observed SOA, leaving a large fraction of SOA still unexplained (Figure S4). It is possible that the volatility distributions of diesel exhaust and IVOC and SVOC surrogates C_{13} n-alkane and C_{23} n-alkane may not be representative of cooking oils.[20] Future work should focus on characterizing SVOCs and IVOCs from cooking to better constrain the resulting formation of SOA.

3.3. Atmospheric Implications. We observed that the rate of generation of SOA from emissions of heated cooking oils was 1 order of magnitude higher than that of POA after 1.9 h of equivalent photooxidation in the presence of NO_x. To the best of our knowledge, this is the first time that SOA formed from emissions of heated cooking oil exceeding its POA has been reported, under OH exposures lower than real atmospheric conditions. The $NMOG:NO_x$ ratios, which were higher than typical urban ratios, may to some extent underestimate SOA formation, as a high level of NO_x could enhance the formation of SOA from aldehydes.[49] Further studies of the NO_x dependence of SOA from cooking are needed. In addition, we solely studied heated cooking oils; other cooking processes, such as boiling and frying food, also likely produce substantial SOA. Given that POA from cooking has been found to contribute 10−34.6% of the total OA in urban areas,[7−13] cooking may also be an important source of SOA in urban areas. In recent years, increasingly strict vehicular emission control regulations have led to large reductions in SOA from vehicle exhaust in some regions, such as the United States.[43] Our findings suggest that the potential relative contributions of cooking emissions to SOA may increase with time and should also be subject to strict regulations.

■ ASSOCIATED CONTENT

ⓢ Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.estlett.7b00530.

Descriptions of smog chamber experiments (Text S1), NMOG measurements (Text S2), OH concentration determinations (Text S3), nonrefractory component measurements (Text S4), production of SOA from NMOG (Text S5), production of SOA from SVOCs and IVOCs (Text S6), a fragmentation table for the most abundant aldehydes (Table S1), alkenal OH reaction rate constants (Table S2), applied SOA yield data (Table S3), $\ln([\text{acrolein}]_0/[\text{acrolein}]_t)$ versus time t (Figure S1), relative contributions of different compounds to the total NMOG (Figure S2), POA ERs versus smoke points of different cooking oils (Figure S3), and estimated contributions of NMOGs to the observed SOA (Figure S4) (PDF)

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