Simulation of vapour phase supersaturation and PM formation during heating commercial cooking oils

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People mostly spend their time indoors which increases the importance of indoor particles. Cooking was found to be one of the main sources of indoor particulate matter (PM). Cooking emissions may have significant effects on human health, and thus, understanding the contribution of cooking elements such as oil to PM emissions is critical. Cooking oils compose of triglycerides such as palmitin and linolein. The primary mechanisms for producing PM by cooking could be the supersaturation of the generated vapour organic compounds due to rapid cooling after mixing with indoor air followed by homogenous or heterogeneous nucleation.

For the first time in the literature, the current study simulated the heating process of several pure commercial cooking oils to predict the supersaturation of the produced organic vapour and resulting particulate matter (PM) mass. Heating of five cooking oils including safflower, soybean, canola, olive and peanut were simulated for the temperature range of 50 to 197°C (Figure 1). Heated oils were mixed with air flow at 23°C and RH=40%, simulating dilution of the produced oil vapour in normal residential kitchens. NARTL activity coefficient model and ideal gas law were employed to predict the phase equilibria of the heated oils. Saturation level of air-oil vapour mixture was estimated by the following equation.

$$S = \frac{P\sum x_i}{P_{dew}}$$

where P_{dew} is dew pressure of the PM phase at the mixture temperature and $P\sum x_i$ is sum of the partial pressure of the condensable components after mixing with air. The PM formation was considered to occur when S values were higher than 1.

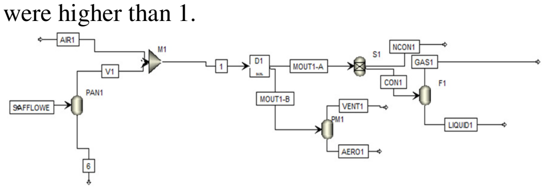

Figure 1. Flow sheet diagram on Aspen Plus

As shown in Figure 2, PM formed when saturation level exceeded 1. Furthermore, the supersaturation and PM mass increased with increased oil temperature. Olive oil was found to produce higher PM mass compared to other studied oils (Figure 3) which is in agreement with the experimental results of Amouei Torkmahalleh et al. (2012). Increased Relative humidity (RH) or moisture content of air flow was found to increase PM mass which could be attributed to the condensation of water vapour onto the PM phase. Further simulation studies were performed to investigate the impact of table salt on supersaturation of the produced vapour chemicals. It was found that addition of table salt to the heated oil reduced the supersaturation level and the PM mass due to the reduced vapour pressure of the organic compounds compared to the heated pure oil at the same temperature. This observation is in good agreement with the experimental finding of Amouei Torkmahalleh et al. (2013).

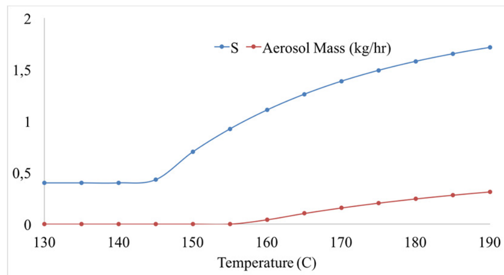

Figure 2. Supersaturation and PM mass over heating temperature for safflower.

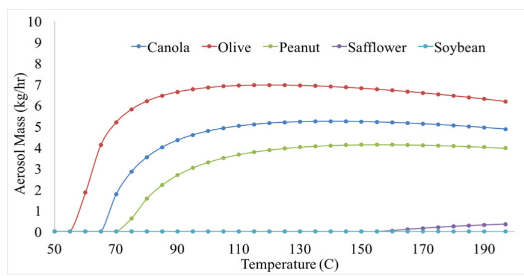

Figure 3. PM mass at different oil temperature for 5 oils

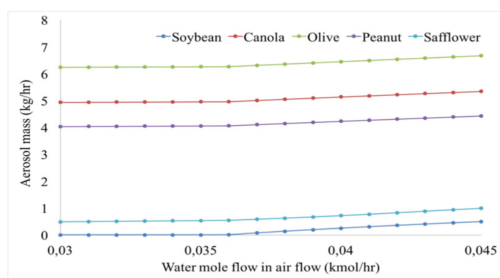

Figure 4. Effect of indoor RH on PM mass

1- Amouei Torkmahalleh, M., Goldasteh, I., Zhao, Y., Udochu, N.M., Rossner, A., Hopke, P.K., Ferro, A.R., (2012). $PM_{2.5}$ and ultrafine particles emitted during heating of commercial cooking oils. *Indoor Air 22*, 483-491.

2- Amouei Torkmahalleh, M., Zhao, Y., Rossner, A., Hopke, P.K., Ferro, A.R. (2013). Additive Impacts on particle emissions from heating low emitting cooking oils, *Atmospheric Environment* 74, 194-198.