Machine Learning-aided Real-time Volatile Organic Compounds Detection Through Robust Colorimetric Sensor Arrays

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Colorimetric sensor arrays (CSA's) have been proposed as an exciting alternative for volatile detection in several areas, like food safety, air quality, and disease detection. They allow for naked-eye odor visualization using chemo-responsive dyes to indicate the presence of various volatile organic compounds (VOCs). Current sensor technologies for monitoring food quality are offline, expensive, and require extensive laboratory analysis; furthermore, the dye indicators rapidly degrade due to environmental stimulation like oxidation and photobleaching, causing baseline drifting. These challenges associated with current VOC sensor technologies limit the ability to monitor the real-time food supply chain. In this work, we fabricate the CSAs by encapsulating the dye into polymerized trimethylolpropane triacrylate, poly(TMPTA), via photosynthesis and tune different polymer coating parameters to achieve both stability and high sensitivity for VOC detection. The results show that the stability and sensitivity of CSA to various volatile compounds are significantly improved through material tunning and dye encapsulation. Using these robust polymer-encapsulated CSAs, we created an inline time-series VOC detection and VOC differentiation system where the detection of VOCs in situ is performed using a transformer convolutional neural network (T-CNN), allowing for the distinguishability of VOCs and time series analysis of VOC concentrations. Ultimately, this work provides online, cost-effective, and robust VOC detection methods through the combination of CSA design and machine learning methodologies, which has great potential in achieving food quality surveillance throughout the supply chain to reduce food waste.