Integrating GC–MS and customized MOX gas sensors for VOC-based discrimination of bacteria: towards applications in sustainable agriculture and food safety

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Abstract

Climate change is increasingly threatening agricultural productivity, particularly in Mediterranean environments where crops are exposed to recurrent drought and soil degradation. In this context, plant growth-promoting bacteria (PGPB), such as *Streptomyces violaceoruber* and *Kocuria rhizophila*, represent a promising sustainable strategy to enhance plant resilience to abiotic stresses. Microbial and plant metabolic activities are closely related to the emission of volatile organic compounds (VOCs), which can serve as non-invasive biomarkers of physiological status and stress conditions. In this study, we combined solid-phase microextraction coupled with gas chromatography-mass spectrometry (SPME/GC-MS) and custom-developed metal oxide (MOX) gas sensors to characterize and monitor VOC profiles from beneficial and pathogenic microorganisms. SPME/GC-MS analyses enabled the identification of species-specific volatilomic signatures in pure cultures of PGPB, revealing putative volatile markers associated with different growth stages. Notably, compounds such as geosmin and 2-methylisoborneol were detected in *S. violaceoruber* cultures and in soil samples, confirming the applicability of the method to real and complex environmental matrices. In parallel, MOX gas sensor arrays coupled with multivariate statistical analysis demonstrated the possibility to discriminate between different bacterial species and subspecies in a rapid and non-invasive manner. This approach was further validated on biological samples artificially contaminated with *Salmonella enterica*, highlighting distinct volatilomic fingerprints. Overall, our results demonstrate that the integration of GC-MS and MOX sensor technologies provides a robust and complementary platform for VOC-based microbial discrimination. This approach represents a promising tool for applications ranging from precision agriculture—through monitoring of PGPB activity and plant health—to food safety diagnostics, paving the way for real-time, in field monitoring systems.

References:

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