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Site-Specific Isotope Analysis Elucidates Mechanisms of Vanillin Degradation Under Biotic and Abiotic Transformations

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Abstract (277 words)

Lignin, Earth's most abundant biopolymer derived from vascular plants, is crucial in terrestrial carbon cycling (Crawford, 1981). It's degradation monomers, such as vanillin, along with their isotope compositions serve as molecular markers to trace the terrestrial organic matter transformation within the carbon cycle (Edelkraut, 1996), and elucidate lignin decomposition pathways and environmental impacts (e.g., Bahri et al., 2008). However, the understanding of how isotopic compositions of vanillin at specific atomic positions are altered through its formation and degradation processes remains limited.

This research examines how biotic and abiotic degradation affects the site-specific carbon isotope composition of vanillin, employing unlabeled compounds with natural isotopic abundances. Preliminary results demonstrate that biotic degradation by *Pseudomonas putida* KT2440, a model soil bacterium (Simon et al., 2014). This form of biotic transformation resulted in an increase in the $d^{13}C$ in the carbonyl carbon in the residual vanillin, with modest changes to other carbons within the molecule. In contrast, abiotic transformation of vanillin via photodegradation also increases the $d^{13}C$ of the aldehyde group of the residue, but with a lesser amplitude than for biotic degradation, and accompanied by larger changes in the $d^{13}C$ of other carbons within the molecule.

This study underscores the efficacy of position-specific isotope analysis for reconstructing environmental degradation processes, as bulk isotope analysis tends to overlook subtle nuances in isotopic composition at the atomic-site level. Our approach of utilizing isotopes in their natural-abundance provides a variety of constraints without the need for prior introduction of labeled substrates, unlike conventional isotope labeling techniques (e.g., Bahri et al., 2008). This enhancement paves the way for future applications in understanding the persistence and transformation of lignin and its monomers within natural settings.

References

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