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Microbial utilization of low molecular weight organic substrates in soil depends on their carbon oxidation state

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Removal of low molecular weight organic substances (LMWOS), originating from plants and microorganisms, from soil solution is regulated by microbial uptake. In addition to the concentration of LMWOS in soil solution, the chemical properties of each substance (e.g. C oxidation state, number of C atoms, number of -COOH groups) can affect their uptake and subsequent partitioning of C within the soil microbial community. The aim of this study was to trace the initial fate of three dominant classes of LMWOS in soil (sugars, carboxylic and amino acids), including their removal from solution and utilization by microorganisms, and to reveal the effect of substance chemical properties on these processes.

Soil solution, spiked at natural abundance levels with ^{14}C-labelled glucose, fructose, malate, succinate, formate, alanine or glycine, was added to the soil and ^{14}C was traced in the dissolved organic carbon (DOC), CO_2, cytosol and soil organic carbon (SOC) over 24 hours. The half-life time of all LMWOS in the DOC ($T_{1/2-solution}$) varied between 0.6-5.0 min showing extremely fast initial uptake of LMWOS. The $T_{1/2-solution}$ of substances was dependent on C oxidation state, indicating that less oxidized organic substances (with C oxidation state "0") were retained longer in soil solution than oxidized substances. The LMWOS-C $T_{1/2-fast}$, characterizing the half-life time of ^{14}C in the fast mineralization pool, ranged between 30 and 80 min, with the $T_{1/2-fast}$ of carboxylic acids (malic acid) being the fastest and the $T_{1/2-fast}$ of amino acids (glycine) being the slowest. An absence of correlation between $T_{1/2-fast}$ and either C oxidation state, number of C atoms, or number of -COOH groups suggests that intercellular metabolic pathways are more important for LMWOS transformation in soil than their basic chemical properties. The CO_2 release during LMWOS mineralization accounted for 20-90% of ^{14}C applied. Mineralization of LMWOS was the least for sugars and the greatest for carboxylic (formic) acids, whereas the ^{14}C incorporations into cytosol and SOC were opposite. The portion of LMWOS mineralized to CO_2 increased with their C oxidation state corresponding to the decrease of C incorporated into the cytosol and SOC pools. The ratio of ^{14}C incorporated into cytosol to ^{14}C incorporated into CO_2 pool ranged between 0.03 and 1.19, being the lowest for carboxylic acids and highest for sugars, and decreased with substances C oxidation state. Thus, the C oxidation state is one of the crucial parameter of LMWOS determining their partitioning between two main C fluxes: mineralization and microbial stabilization/immobilization. Our data suggests that the uptake of common LMWOS from soil solution by microorganisms and final LMWOS-C partitioning within microbial biomass may be possible to predict from the physicochemical properties of the substance.