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Fate of low molecular weight organic substances in an arable soil: From microbial uptake to utilisation and stabilisation

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ABSTRACT

Microbial uptake and utilisation are the main transformation pathways of low molecular weight organic substances (LMWOS) in soil, but details on transformations are strongly limited. As various LMWOS classes enter biochemical cycles at different steps, we hypothesize that the percentage of their carbon (C) incorporation into microbial biomass and consequently stabilisation in soil are different.

Representatives of the three main groups of LMWOS: amino acids (alanine, glutamate), sugars (glucose, ribose) and carboxylic acids (acetate, palmitate) – were applied at naturally-occurring concentrations into a loamy arable Luvisol in a field experiment. Incorporation of ^{13}C from these LMWOS into extractable microbial biomass (EMB) and into phospholipid fatty acids (PLFAs) was investigated 3 d and 10 d after application. The microbial utilisation of LMWOS for cell membrane construction was estimated by replacement of PLFA-C with ^{13}C.

35–80% of initially applied LMWOS-^{13}C was still present in the composition of soil organic matter after 10 days of experiment, with 10–24% of ^{13}C incorporation into EMB at day three and 1–15% at day 10. Maximal incorporation of ^{13}C into EMB was observed from sugars and the least from amino acids. Strong differences in microbial utilisation between LMWOS were observed mainly at day 10. Thus, despite similar initial rapid uptake by microorganisms, further metabolism within microbial cells accounts for the specific fate of C from various LMWOS in soils.

^{13}C from each LMWOS was incorporated into each PLFA. This reflects the ubiquitous utilisation of all LMWOS by all functional microbial groups. The preferential incorporation of palmitate into PLFAs reflects its role as a direct precursor for fatty acids. Higher ^{13}C incorporation from alanine and glucose into specific PLFAs compared to glutamate, ribose and acetate reflects the preferential use of glycolysis-derived substances in the fatty acids synthesis.

Gram-negative bacteria (16:1ω7c and 18:1ω7c) were the most abundant and active in LMWOS utilisation. Their high activity corresponds to a high demand for anabolic products, e.g. to dominance of pentose-phosphate pathway, i.e. incorporation of ribose-C into PLFAs. The ^{13}C incorporation from sugars and amino acids into filamentous microorganisms was lower than into all prokaryotic groups. However, for carboxylic acids, the incorporation was in the same range (0.1–0.2% of the applied carboxylic acid ^{13}C) as that of gram-positive bacteria. This may reflect the dominance of fungi and other filamentous microorganisms for utilisation of acidic and complex organics.

Thus, we showed that despite similar initial uptake, C from individual LMWOS follows deviating metabolic pathways which accounts for the individual fate of LMWOS-C over 10 days. Consequently, stabilisation of C in soil is mainly connected with its incorporation into microbial compounds of various stability and not with its initial microbial uptake.

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