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The influence of cellulose crystallinity on its microbial decomposition in boreal forest soils

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Cellulose is the dominating biopolymer in plant biomass and soil organic matter (SOM) and its decomposition is thus of crucial importance for soil carbon balances. Degradability of cellulose is normally considered a function of lignification through its existence in lignocellulose complexes. However, the degree of cellulose crystallinity also has the potential to constitute a master control on its hydrolysis and decomposition in soils.

The aim of this study was to elucidate how cellulose mineralization in soils is influenced by the degree of structural crystallinity. We used a highly crystalline cotton linter cellulose (60% crystalline, 40%amorphous) and modified its structure to reduce the degree of crystallinity down to 0% (100% amorphous) using an ionic liquid. The different forms of cellulose generated by the IL treatment were then amended to soil samples with and without stoichiometric amounts of nutrients (N, P &K) and incubated at 9 and 19 °C for up to 4 months. The soil samples originated from the organic surface soil horizon in a mature boreal spruce forest stand. CO_2 production from the incubated samples were measured hourly and the total rates of mineralization were modelled assuming carbon use efficiencies (CUEs) in the range of 0.4 to 0.6. CUEs had previously been determined in soil samples from the same site based on microbial growth on 13C-labelled cellulose.

The presence of inorganic nutrients greatly enhanced cellulose mineralization, which is expected due to the documented requirement of e.g. N for efficient exo-enzyme generation and cellulose decomposition. Moreover, mass balance calculations revealed the fraction of the different celluloses decomposed was determined by its structure where the amorphous cellulose was decomposed while the crystalline fractions remained intact. The calculated temperature response coefficients at maximum CO_2 production rates on cellulose decomposition (Q10=1.6) was significantly higher as compared to that of monomeric glucose (Q10=1.3), but did not differ among cellulose types nor in comparison to the basal respiration rates in samples observed prior to cellulose additions.

We can conclude that the structure of cellulose, involving its degree of crystallinity, can control its decomposition rate and consequently its accumulation in boreal forest soils. This aspect deserves more attention in the studies of decomposition and recalcitrance of SOM, and should be considered in addition to e.g. thermodynamic dimensions of SOM decomposition linked to the organo-chemical composition of organic matter, as well as the physical protection of cellulose attributed to lignification.