Measurements of leaf sucrose to explain variability in hydrogen isotope composition of leaf cellulose

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The hydrogen isotope composition (δ²H) of cellulose has been used to assess ecohydrological processes and carries metabolic information, adding new understanding to how plants respond to environmental change. However, experimental approaches to isolate drivers of δ²H variation is limited to the Yakir & DeNiro model (1990), which is difficult to implement and largely unvalidated. Notably, the two biosynthetic fractionation factors in the model, associated with photosynthetic (εₐ) and post-photosynthetic (εₜ) processes are currently accepted as constants, and the third parameter – the extent to which organic molecules exchange hydrogen (fₕ) with local water – is usually tuned in order to resolve the difference between modelled and observed cellulose δ²H values. Thus, by virtue, the metabolically interpretable parameter is only fₕ, whilst from theory, metabolic flux rates will also impact on the apparent fractionations. To overcome part of this limitation, we measured the δ²H of extracted leaf sucrose from fully-expanded leaves of seven species and a phosphoglucomutase ‘starchless’ mutant of tobacco to estimate the isotopic offset between sucrose and leaf water (εₛucrose). Sucrose δ²H explained ~60% of the δ²H variation observed in cellulose. In general, εₛucrose was higher (range: -203‰ to -114‰; mean: -151 ± 21‰) than the currently accepted value of -171‰ (εₐ) reflecting ²H-enrichment downstream of triose-phosphate export from the chloroplast, with statistical differences in εₛucrose observed between species estimates. The remaining δ²H variation in cellulose was explained by species differences in fₕ (estimated by assuming εₜ = +158‰). We also tested possible links between model parameters and plant metabolism. εₛucrose was positively related to dark respiration (R²=0.27) suggesting an important branch point influencing sugar δ²H. In addition, fₕ was positively related to the turnover time (τ) of water-soluble carbohydrates (R²=0.38), but only when estimated using fixed εₐ = -171‰. To decipher and isolate the “metabolic” information contained within δ²H values of cellulose it will be important to assess δ²H values of non-structural carbohydrates so that hydrogen isotope fractionation during sugar metabolism can be better understood. This study provides the first attempt at such measurements showing species differences in both source and sink processes are important in understanding δ²H variation of cellulose.