Chemical and Carbon Isotopic Characteristics of Ash and Smoke Derived From Burning of C₃ and C₄ Grasses

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Introduction

Because of the climatic effects of fires, there has been increased interest in reconstructing the history and dynamics of past fire regimes (Conedera et al., 2009). The significance of BC in sediments and soils as a tracer of fire history has been recognized (e.g. Preston and Schmidt, 2006; Zhou et al., 2007). Stable isotope analysis of charcoal or BC in soils and sediments has also been used to study past changes in terrestrial ecosystems (e.g. Jia et al., 2003). The basic assumption of this type of study is that the δ¹³C composition of charcoal or BC is the same as the original biomass from which it is derived. However, recent studies suggest that the stable C isotope ratios of char or BC may not faithfully record the C isotopic signatures of the source vegetation. We report here the results from controlled laboratory burning experiments designed to investigate whether biomass burning induces any significant changes in the chemical characteristics and stable C isotope ratios of ash and smoke in comparison with the original vegetation.

Results and Discussion

The results show that smoke produced from C₄ grasses is generally depleted in ¹³C relative to the original plant, but the magnitude of the ¹³C depletion varies with species from less than 0.5‰ to a maximum of 7.2‰. Ash derived from C₄ grasses, on the other hand, is either depleted (by 0.1 to 3.5‰) or slightly enriched (<1‰) in ¹³C relative to the original grass depending on species. In contrast, both smoke and ash produced from C₃ plants do not show any significant deviation in δ¹³C from that of the original plant material. Our data also show that the C isotope fractionation between ash and smoke and the original plant material depends not only on plant species and plant type but also on burning temperature. Multi-elemental thermo analysis of ash, smoke and original plant material reveal distinctly different chemical characteristics for these materials. C₄ grass appears to be more thermally stable than C₃ grass. Ash is preferentially enriched in compounds with higher thermal stability whereas smoke contains a wide spectrum of compounds with different stability in comparison with the original plant material. It appears that the ash and smoke with the highest BC content also displayed the largest ¹³C depletion relative to the original plant material (i.e., centipede). However, more data are needed in order to establish any quantitative relationship (if there is any) between BC content and C isotopic composition of the samples.

Conclusions

Burning generally results in ¹³C-depleted smoke and ash derived from C₄ grasses but the same effect was not observed for C₃ grasses. The isotope fractionation for C₄-derived ash and smoke appears to be species dependent, as different C₄ species gave different isotopic signatures for ash and smoke samples. Isotopic differences among ash, smoke and plant most likely reflect differences in their chemical make up, as revealed by MESTA. Thermograms show that C₄ grass appears to be more thermally stable than C₃ grass and that smoke contains a wide range of compounds with various thermal stability while ash is enriched in compounds with higher thermal stability compared to original plant material. The results have important ramifications for ecological and paleoecological studies using δ¹³C signatures of BC or charcoal in soils and sediments. Ecological or paleoecological studies utilizing the δ¹³C values of BC or charcoal, without considering burning-induced C isotopic fractionation, would underestimate the proportion of C₄-derived organic matter in modern soils or ancient sediments.

References