Effect of vermiculite modification and carbonization temperatures on carbon retention and stability of biochar derived from rice straw

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Introduction
Biochar is considered a promising material for locking CO₂ from the atmosphere, thus helping to alleviate climate change when returned to the soil. Biochar stability is the most decisive factor determining its C sequestration potential. Mineral modification may improve biochar characteristics, but systematic research on the effect of mineral modification on the C retention and stability of biochar and the associated mechanisms is limited.

Materials and methods
Vermiculite: (Mg,Fe,Al)₂[(Si,Al)₄O₁₀(OH)₈]·4H₂O, analytical reagents
The vermiculite was mixed with rice straw at a ratio of 1:4 (w/w).

Biochar yield: Y = (Mₙ − M₀) / M₀ × 100
C retention ratio: Rₖ = (Y × Cₖ)/C₀ × 100%

Biochar heat stability is represented by the thermal weight loss ratio of C in biochar, which was measured according to the mass loss of C in the biochar samples by a thermogravimetric analyzer (Q50, TA, USA). The chemical stability of biochar was determined by chemical oxidation treatment, in which experimental K₂Cr₂O₇ was used to assess the labile fraction of C in the biochar samples.

Results

The C and total mineral contents of all the biochars increased with increasing temperature, whereas the H and O contents decreased. After modification, the C content decreased, whereas the mineral content increased.

The unmodified biochar is rich in mineral components, such as Al, Ca, Fe, K, Mg, P, and Si. After vermiculite modification, the Al, Fe, Mg, and Si contents increased with increasing temperature.

- The yield and C retention ratio decreased with increasing temperatures but increased after modification. The C thermal weight loss, H/C atomic, and C oxidation loss ratios of biochar were reduced with increasing temperature, indicating improved thermal, aromatization, and chemical oxidation stability.

Conclusions
- With increasing carbonization temperature, the C content of rice-straw biochar gradually increased, whereas the yield and C retention ratio gradually decreased.

- Compared with that of the unmodified biochar, the C content of the vermiculite-modified biochar decreased significantly, but the yield and C retention ratio increased significantly.

- The thermal weight loss, H/C atomic, and C oxidation loss ratios of biochar gradually decreased with increasing temperature, indicating that the thermal, aromatization, and chemical oxidation stability of biochar were enhanced.

- Vermiculite modification enhanced biochar stability by increasing the content of mineral components, promoting the formation of chemical bonds, such as Si–O and Fe–O, on the biochar surface, and improving the aromatization rate during carbonization.