Short communication

Flame retardant properties of the bark powder of Anadenanthera peregrina var. falcata (Benth.) Altschul (angico) studied by coupled thermogravimetry–Fourier transform infrared spectroscopy

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1. Introduction

The Anadenanthera peregrina var. falcata (angico) is a plant species of the family Fabaceae and is a characteristic tree of the Brazilian Cerrado with high frequency and dispersion in this type of land, occurring in primary and secondary formations. It is a rustic plant resistant to droughts and even forest fires [1] and is widely used in construction, joinery and carpentry. The fire resistance exhibited by these structures is often attributed to the morphological features of this plant in such a way that the bark would exert a physical protection, functioning as a thermal insulator during fires and thus protecting the sapwood of the stem [2]. However, it is questionable whether other factors associated with bark would participate in such protection.

The occurrence of fires in the Brazilian Cerrado is one of the major environmental concerns due to the rich biodiversity of this ecosystem, constituted by more than 10,000 species of plants, being that around 4400 ones are endemic [3]. Every year, public and private sectors make many efforts in operations for both prevention and firefighting.

Among the several thermal methods of analysis employed to characterize solid compounds, evolved gas analysis (EGA) using coupled thermogravimetry–Fourier transform infrared spectroscopy (TG–FTIR) is widely used to evaluate properties of organic compounds since it can provide extremely useful information about the volatile products generated during thermal decomposition processes [4]. EGA studies using coupled TG–FTIR analysis have already been used, for example, to investigate the pyrolysis of wood lignin and the pyrolysis of poplar wood sawdust [5,6].

A. peregrina var. falcata stands out amid the various tree species in Cerrado for its high resistance against fires. This unique feature encouraged us to explore this plant using TG–FTIR techniques. In the present paper, we present some evidences about the mechanism adopted by this tree to survive in the arid habitat of Cerrado [7].

2. Experimental

Simultaneous thermogravimetry–differential scanning calorimetry (TG–DSC) curves were recorded on a TGA/DSC 1 STAR® System from Mettler-Toledo under the following experimental conditions: open α-alumina crucibles, heating rate of 20 °C min⁻¹, in an air atmosphere with flow rate of 100 mL min⁻¹ and samples of about 7 mg. Differential scanning calorimetry (DSC) curves were recorded using a DSC Q10 modulus from TA instruments under an air flow of 100 mL min⁻¹, at a heating rate of 20 °C min⁻¹, using covered aluminum crucibles with a pin hole (φ = 0.7 mm) and sample masses of about 2 mg. The DSC modulus
was calibrated using indium metal (99.99%+) for temperature and enthalpy. Coupled TG–FTIR analyses were performed with a Nicolet iS10 IR spectrophotometer from Thermo Scientific coupled to the gas exhaust of the TGA/DSC 1 STAR System. The attenuate total reflectance infrared spectra of the bark powder were recorded on a Nicolet iS10 IR (Thermo Scientific) an ATR accessory with Ge window.

3. Results and discussion

The TG–DSC curves of the A. peregrina var. falcata bark powder are shown in Fig. 1. The TG curve shows that the sample is stable up to 195 °C, when thermal decomposition begins, occurring as a single step up to 620 °C. The first mass loss, between 40 and 140 °C, is associated with the dehydration of the sample (Δm₂ = 9.10%). The second step is observed between 195 and 620 °C (Δm₂ = 90.36%), with exothermic peaks at 363 and 495 °C, and is attributed to the oxidation of the organic matter. The final residue of 0.54% is due to ashes and non-volatile inorganic compounds.

The DSC curve of A. peregrina var. falcata bark powder is shown in Fig. 2. The endothermic peak at 84 °C, which is associated with a mass loss in the TG, was firstly attributed to the dehydration of the sample (ΔH = 200.5 J g⁻¹). However, the TG–FTIR analysis indicated that the release of carbon dioxide may give a contribution to this endothermic event.

Fig. 1. TG–DSC curves of Anadenanthera peregrina var. falcata bark powder (m = 7.080 mg).

Fig. 2. DSC curve of Anadenanthera peregrina var. falcata bark powder (m = 2.075 mg).

Fig. 3. 3D infrared spectra of the gases evolved from the thermal decomposition of Anadenanthera peregrina var. falcata bark powder between 30 and 700 °C.

Fig. 4. FTIR infrared spectra of (a) gas collected at 140 °C, (b) CO₂ spectrum from the HR TGA vapor phase Thermo Fisher Scientific Inc. [8] and (c) H₂O spectrum from the HR TGA vapor phase Thermo Fisher Scientific Inc. [8].
4. Conclusion

The TG–DSC curves supplied information about the thermal stability and thermal decomposition of the A. peregrina var. falcata bark powder. The DSC curves allowed us to determine the enthalpy associated with the release of water and carbon dioxide ($\Delta H = 200.5 \text{J g}^{-1}$), whose eliminations in the first mass loss were evidenced in the EGA analysis by coupled TG–FTIR. A sample of the bark powder of angico was heated to 150 °C and its FTIR spectrum showed a decrease in the amount of water (absorption bands at 3400 and 1610 cm$^{-1}$). The strong endothermic peak associated with the release of H$_2$O and CO$_2$ at low temperatures may be responsible for the flame retardant properties of this plant.

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References