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Instrumental analytical technologies for wood research

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ABSTRACT

Wood is a commodity produced in Brazil that is relevant in the economic scenario, however, the environmental impact, due to the expansion of exploration areas, has generated concern about deforestation and consequent environmental changes, especially in the Amazon region. In the present investigation, three instrumental analytical methodologies were tested for the authentication of native wood from the Amazon based on its physicochemical characterization. The combined use of spectrometric techniques such as X-ray Fluorescence (XRF), as well as analysis of organic compounds by Raman (ER) and Infrared (IR) spectroscopy proved to be efficient for use in forensic metrology, providing data that can be used in the identification of native wood, composing an alternative methodology for monitoring the problems faced in the Amazon region (deforestation, fires and illegal invasions). In addition, the methodology established in this study can be applied to other regions of Brazil, which also produce this type of commodity and face the same problems.

Keywords: Native wood, Amazon, X-ray fluorescence (XRF), Raman spectroscopy, Forensic identification, Deforestation.

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INTRODUCTION

Commodities are products of agricultural origin or mineral extraction, produced on a large scale, which provide raw material for different sectors of society. Its main types are: agricultural, livestock, environmental and mineral. Wood is an environmental commodity that has economic weight in Brazil's trade balance, however the environmental impact due to the expansion of logging areas (deforestation), as well as invasions for illegal cultivation and fires, has generated concern, especially in the Amazon. The consequences are serious and range from loss of biodiversity, risk of extinction of wild animals, climate change and the hydrological cycle, in addition to significant financial losses [1-4].

The problem that is intended to be addressed in the present investigation is the establishment of a forensic mechanism, using analytical techniques, that can identify the origin of this environmental commodity and assist in the monitoring of its production chain. Multi-element investigation carried out by Neutron Activation Analysis (NAA) [5] proved to be efficient in the geographic discrimination of samples of livestock commodities (beef) from different Brazilian biomes [6], as well as samples of agricultural commodity (soybean) from regions of Argentina [7]. The AAN technique offers several advantages, such as high sensitivity and selectivity, but requires thorough pre-treatment of the sample and/or longer time for analysis, in addition to the need to use a neutron source (Nuclear Reactor). Combined X-ray Fluorescence (XRF), Fourier Transform Infrared (FTIR) and Raman Spectroscopy (ER) analyses, which are often used as quality control (because they are fast, simple and accurate) can compose alternative metrology that helps in the identification of wood. The objective of the present study is to implement an alternative analytical procedure that can be used in the identification of native wood from the Amazon region.

MATERIAL AND METHODS

ENERGY DISPERSIVE X-RAY FLUORESCENCE (FRXDE)

The Energy Dispersive X-ray Fluorescence (FRXDE) technique [8] is based on the measurement of the characteristic radiations emitted by the elements of the sample (in this case, wood), when excited with X-rays. The samples can be analyzed in natura and in the form of loose powder packed in a polyethylene sample holder with a 4 micron thick polypropylene base. In the XRF equipment (model X-123 SDD Complete X-Ray Spectrometer – Amptek®) the X-rays from the wood sample are selected by means of electronic pulses produced by a Silicio Drift detector (SDD) and identified by their characteristic X-ray energies.

FOURIER TRANSFORM INFRARED SPECTROSCOPY (FTIR)

Fourier Transform Infrared Spectroscopy (FTIR) is an analytical technique used for the identification, characterization and quantification of organic and inorganic materials [9-11]. Through the analysis of infrared spectra, it is possible to obtain information about the molecular vibrations present in the sample. These vibrations are directly related to the chemical bonds present in the sample, making it possible to identify its chemical composition. The FTIR assay is performed in an infrared spectrometer equipped with a Michelson interferometer. The wood sample is exposed to a beam of infrared light that interacts with the molecules in the sample, causing absorption at specific frequencies (corresponding to molecular vibrations) creating an interferogram that contains information about the absorption of light by the sample at different frequencies. This interferogram is subjected to a Fourier transform, resulting in the infrared spectrum, which represents the absorption intensity as a function of the wavenumber or wavelength.

RAMAN SPECTROSCOPY (ER)

Raman Spectroscopy [10, 11] is a technique that allows the identification of the chemical structure of the analyzed material (wood). The information obtained is extracted from the scattering suffered by electromagnetic radiation after its interaction with the material, which can be inorganic or organic. The technique is complementary to FTIR spectroscopy, making it possible to identify a greater number of peaks for the same sample.

RESULTS

To evaluate the performance of the proposed assays, the XRF, ER and FTIR techniques were tested for two different wood samples (A1 and A2), from Rolim de Moura, Rondônia (Table 1 and Figure 1), which is part of the Amazon biome. The samples were crushed in mortar, calcined and compacted in the form of tablets (~80mg). All measurements were performed in triplicate. The results are presented in Figures 2, 3, 4 and 5 for XRFS analyses. In Figures 6 and 7, the spectroscopic analyses by FTIR and Raman, respectively.

Figure 1. Map of Brazil with the location of Rolim Moura – RO. Source: Adapted from Canva

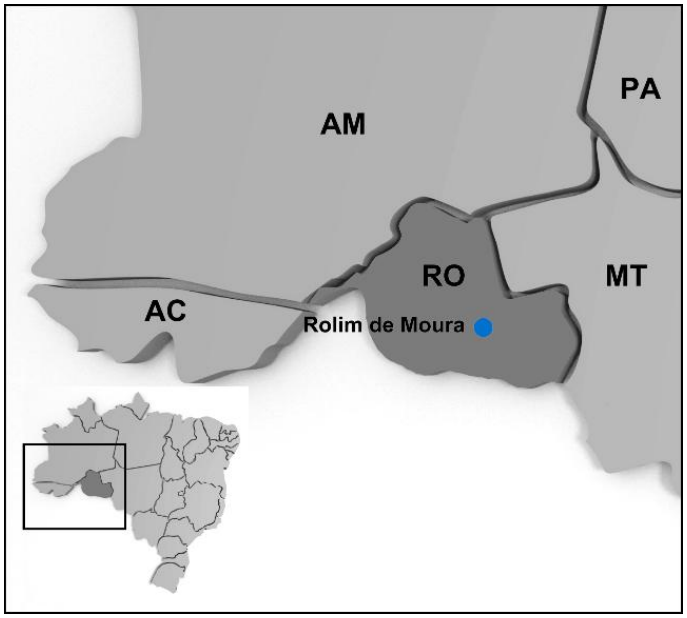


Table 1. Identification of wood samples

Samples Wood	Species	Family	Latitude	Longitude
A1	*Endopleura uchi*	Humiriaceae	-9.8591	-62.7472
A2	*Martiodendron elatum*	Fabaceae	-9.8544	-62.7542

Figure 2. Percentage distribution of XRFF analyses in the wood sample of the species *Endopleura uchi* (A1).

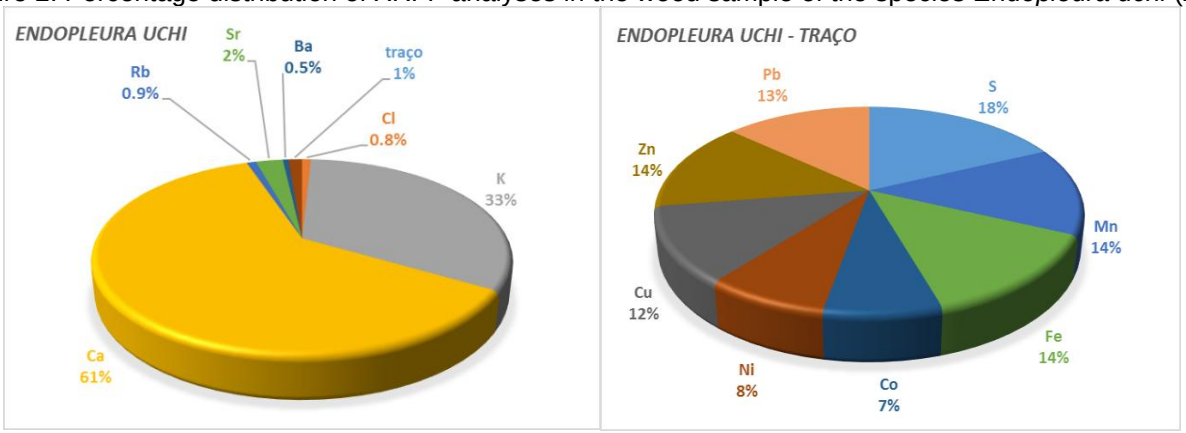


Figure 3. Percentage distribution of XRFF analyses in the wood sample of the species *Martiodendron elatum* (A2).

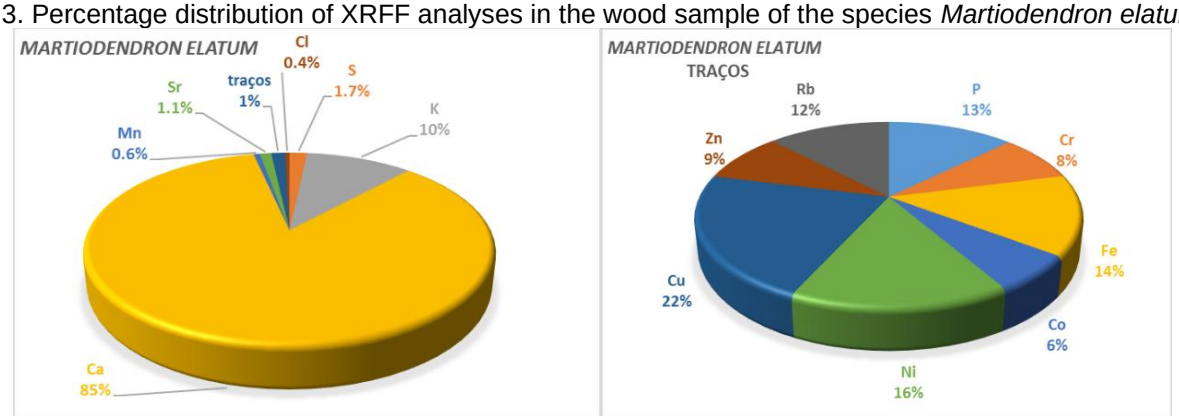
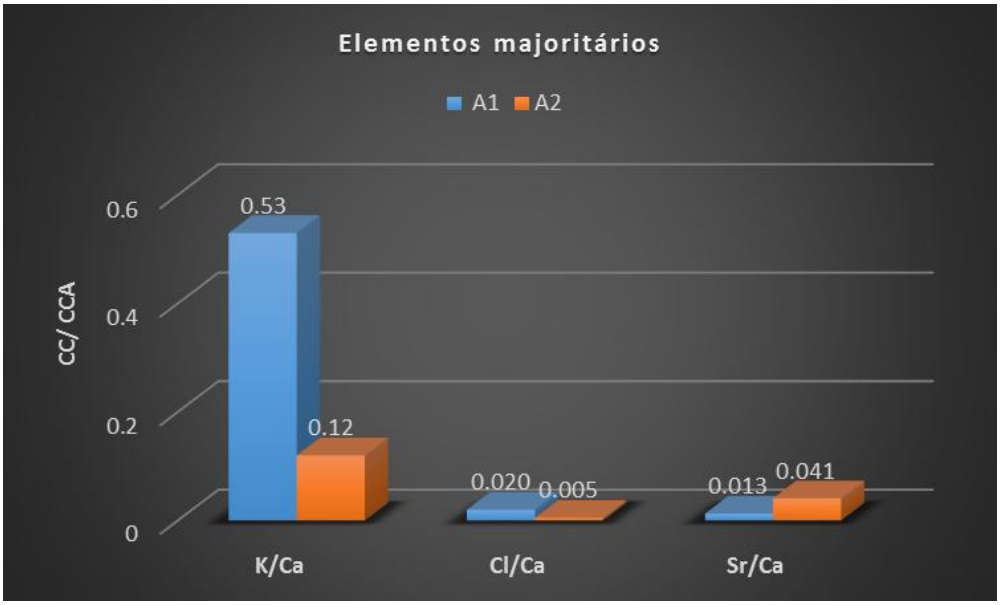
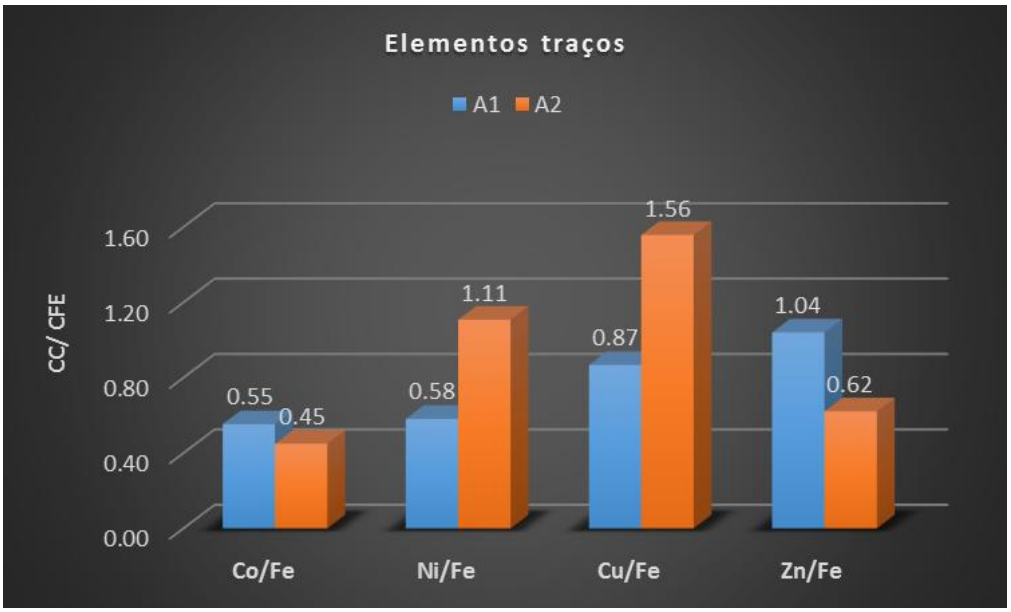


Figure 4. Ratio between the concentrations of the elements as a function of Calcium (Cc/CCa) in the wood samples (A1 and A2)



Cc: concentration of major elements (in common) in the wood samples
CCa: Ca concentration in wood samples

Figure 5. Ratio between the concentrations of trace elements as a function of Iron (Cc/CFe) in wood samples (A1 and A2)



Cc: concentration of trace elements (in common) in the wood samples
CFe: Iron concentration in wood samples

Figure 6. Analysis of wood samples by FTIR for samples A1 and A2

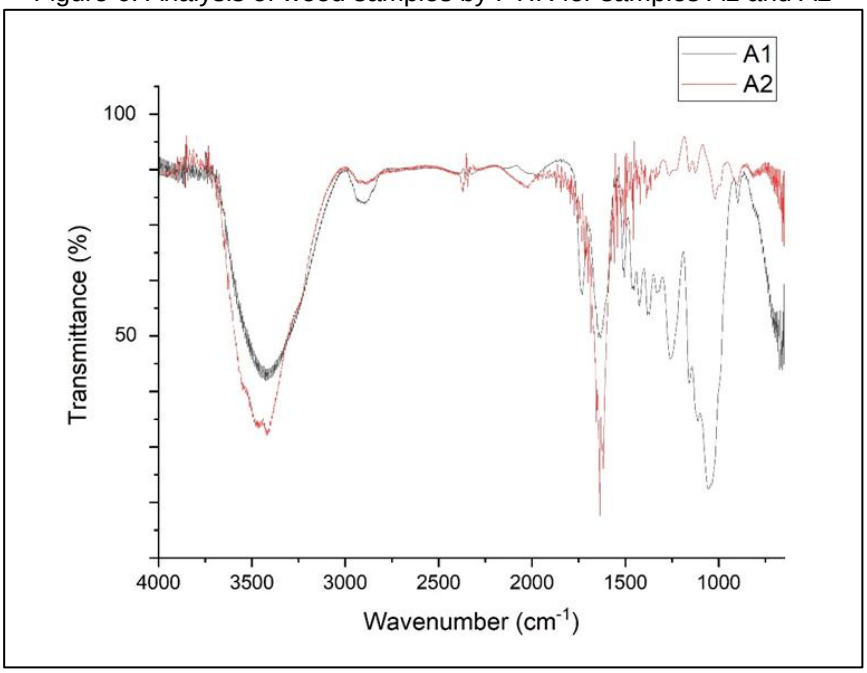
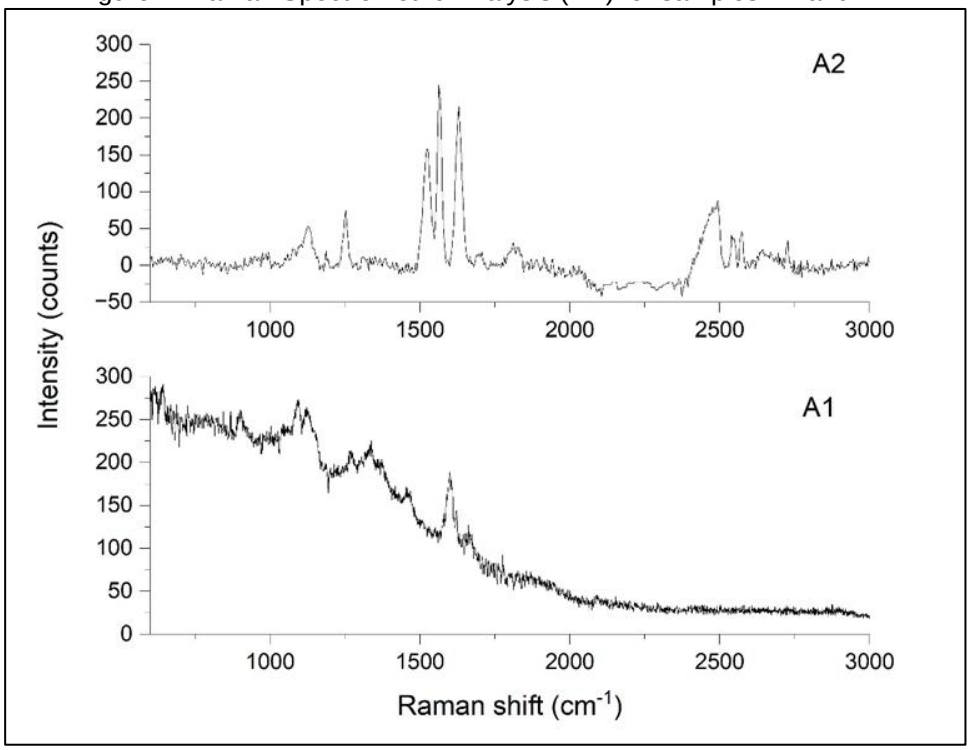


Figure 7. Raman Spectrometric Analysis (ER) for samples A1 and A2



The XRFR results emphasize quantitative differences between the major elements (Ca, Cl, K and Sr) in the samples of *Endopleura uchi* (A1) and *Hymenolobium modestum* (A2), as well as in trace elements in A1 (S, Mn, Fe, Co, Ni, Cu, Zn and Pb) and A2 (P, Cr, Fe, Co, Ni, Cu, Zn and Rb). In addition, there are qualitative differences in the samples, such as the presence of Pb and Ba in A1 and of Cr and Rb in A2. Similarly, FTIR and ER spectroscopy analyses show significant differences between A1 and A2 in the regions of 1000 to 1500 $^{cm-1}$ and 1500 to 3000 $^{cm-1}$, respectively.

CONCLUSION

The combination of analytical resources employed (FRX, ER and IFTR) proved to be efficient in providing data that can be used in the identification of native wood, contributing to the management of the production chain, in the monitoring of deforestation and indirectly in the fight against illegality (due to irregular invasions and fires) which are the major problems faced in the Amazon region.

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