SPECTRAL DATA FROM 22 AMAZON BIOME TREE SPECIES

M. M. Redígolo[1], T. Zanin[1], C. B. Zamboni[1]

[1] Centro do Reator de Pesquisas (CERPq), Instituto de Pesquisas Energéticas e Nucleares (IPEN), Av. Prof. Lineu Prestes, 2242 – Cid. Universitária, São Paulo - SP

Abstract:
A pilot study involving instrumental analytical techniques (XRF, FTIR, and Raman) was performed to investigate twenty-two wood species from Rolim de Moura (Rondônia), with the goal of creating a spectral database to identify wood species to be exported from Brazil. The results are promising and may help authorities identify illegal timber exports.

Keywords: x-ray fluorescence, Raman, FTIR, wood

DADOS ESPECTRAIS DE 22 ESPÉCIES DE ÁRVORES DO BIOMA AMAZÔNICO

Resumo: Um estudo piloto envolvendo técnicas analíticas instrumentais (XRF, FTIR e Raman) foi realizado para investigar vinte e duas espécies de madeira de Rolim de Moura (Rondônia), com o objetivo de criar um banco de dados espectral para identificar espécies de madeira a serem exportadas do Brasil. Os resultados são promissores e podem auxiliar as autoridades na identificação de exportações ilegais de madeira.

Palavras-chave: fluorescência de raios X, Raman, FTIR, madeira

1. Introduction

According to the Ministry of Development, Industry, Commerce and Services (MDIC), circa 6.7 million m^3 of wood were exported in 2023, being China, The Netherlands and the USA the main buyers (SNIF, 2025). Nevertheless, these numbers do not account for the thousands of cubic meters of illegal timber that reach those countries. According to EIA (Environmental Investigation Agency, 2025), more than a third of Amazon wood has its source in illegal logging. A countermeasure to this environmental crime is to certificate the wood export by controlling its origin.

Standard wet chemical methods of wood classification are time consuming, despite being accurate. They usually require the use of chemical reagents, sample pretreatment and are labor-intensive (Krasznai, 2017). Whereas spectroscopic methods are sensitive, precise and fast. The scope of this work was to employ techniques which, besides being fast and demand little or no sample preparation, would also provide a portable configuration. Vibrational spectroscopy and x-ray fluorescence (XRF) spectroscopy have been widely employed in characterizing wood species (Agarwal, 2019; Shugar, 2021; Jesus, 2024).

Wood species differentiation is based on comparing the concentrations of cellulose, hemicellulose and lignin in each sample. Cellulose is a linear polysaccharide with high structural integrity; hemicellulose is a heteropolysaccharide of pentose and hexose, usually crosslinked across lignin and cellulose; lignin is a highly branched aromatic heteropolymer providing structure to cellulose fibers (Rowell, 2012).

Therefore, Fourier transform infrared (FTIR), and Raman spectroscopies can yield a different spectrum for each species, while XRF presents information about their elemental composition. Spectra can be the input of a machine learning system to deliver fast and reliable identification of wood species at Brazilian borders by Federal Police as an aid to reducing illegal logging.

2. Materials and Methods

A total of 22 wood species from Rolim de Moura (Rondônia) were analyzed. The samples were ground to powder. Elements representing up to 10% of the peak intensity of the major element (i.e., the one with the highest count rate per unit time) in each wood sample were considered as trace elements.

2.1. XRF spectroscopy

The XRF spectrometer (model XR-100SDD from Amptek) consists of an X-ray mini-tube, with a silver (Ag) target, a Silicon Drift Detector (SDD: 25 mm^2 x 500 µm) with a Beryllium window (12.5 µm), coupled with a preamplifier, digital pulse processor and multichannel. Wood samples (powder) were prepared in triplicate. The EDXRF measurements were performed using 200s of counting time, 15 µA and voltage of 30 KV. Instrument calibration was performed using NIST standard reference material 1573a (tomato leaves) for elements ranging from low to high Z and results are summarized as: relative standard deviation (SRD, %) 0.4 – 3.6; sensitivity (cps g^{-1} kg) 3.35 – 175.48; detection limit (g kg^{-1}) 0.09 – 3.09.

2.2. FTIR spectroscopy

The Bruker benchtop FTIR model Invenio S coupled with a Specac Quest ATR module was employed and the instrumental parameters were resolution 4 cm^{-1}; background scan time: 64 scans; sample scan time: 64 scans; spectral range: 4000 to 400 cm^{-1}; DLaTGS detector, phase correction mode: Mertz; Apodization function: Happ-Genzel. A certified polystyrene calibration film was employed for the calibration.

2.3. Raman spectroscopy

The Horiba Confocal Raman Microscope XploRA Plus model was employed with the following instrumental parameters: range: 40 to 4000 cm^{-1}; acquisition time: 10 seconds, accumulation: 5 scans; laser: 532 nm; filter: 25%; grating: 1200 (750 nm); slit 100 µm; hole: 300 µm. The equipment was calibrated employing an acetylsalicylic acid reference material.

3. Results and Discussion

Results are presented in Table1 and Figures 1 and 2. Table 1 presents samples concentration by XRF analysis (in %) with the species name and its major and trace elements. Figure 1 presents Raman spectra of the species and Figure 2 the FTIR spectra.

Table 1. Summary of wood powder elemental concentration by XRF spectroscopy

WN – ***Scientific Name*** *Popular name*	**Major elements (%)**	**Trace elements (%)**
W01 – ***Dialium Guianense*** *Pororoca*	Cl(6.0), Ca(18.2), Cr(3.7), Mn(5.2), Fe(46.0), Co(7.0), Ni(5.9)	Si(1.0), P(1.7), S(1.6), Ti(1.0), Rb(1.5), Sr(1.1)
W02 – ***Peltogyne paniculata*** *Roxinho*	Cl(3.2), Ca(63.4), Mn(6.0), Fe(13.3), Co(2.8), Ni(2.5)	P(1.4), S(0.9), Ti(0.9), Cr(1.8), Cu(0.8), Zn(1.1), Rb(0.5), Sr(1.4)
W03 – ***Nectranda spp.*** *Canela*	Cl(5.4), Ca(18.4), Cr(2.6), Mn(8.9), Fe(45.0), Co(3.5), Ni(3.5), Br(2.3)	P(1.8), S(1.0), Ti(2.1), Cu(1.4), Zn(1.8), Rb(1.2), Sr(1.1)
W04 – ***Martiodendron elatum***	Cl(2.5), Ca(40.4), Cr(2.3),	P(1.1), S(1.4), Ti(0.8),

Tamarindo	Mn(3.7), Fe(33.4), Co(5.0), Ni(4.1)	Cu(1.7), Zn(1.6), Rb(1.1), Sr(0.8)
W05 – ***Castilla elastica*** *Caucho*	Cl(3.6), K(51.1), Ca(24.6), Mn(3.6), Fe(7.1)	Al(0.1), P(0.6), S(1.1), Ti(0.4), Cr(1.1), Co(2.1), Ni(1.7) Cu(0.7), Zn(0.5), Rb(0.9), Sr(0.7)
W06 – ***Anadenanthera colubrina*** *Angico-Branco*	S(4.8), Cl(5.6), K(15.7), Ca(29.3), Cr(2.7), Mn(10.9), Fe(13.8), Co(4.9), Ni(4.1)	P(1.5), Ti(1.0), Cu(1.9), Zn(1.1), Rb(1.7), Sr(1.0)
W07 – ***Dipteryx odorata*** *Cumaru*	P(2.6), Cl(8.9), Ca(58.1), Cr(2.4), Mn(5.7), Fe(10.1), Co(2.9), Ni(2.7)	S(1.3), K(1.2), Ti(1.7), Cu(1.0), Rb(0.7), Sr(0.8)
W08 – ***Hymenaea courbaril*** *Jatobá*	P(2.2), Cl(4.3), K(14.5), Ca(22.2), Cr(3.3), Mn(13.8), Fe(19.5), Co(6.0), Ni(5.1)	S(1.0), Ti(1.4), Cu(1.9), Zn(1.6), Rb(2.0), Sr(1.2)
W09 – ***Couratari oblongifolia*** *Tauari Branco*	S(3.2), K(23.7), Ca(31.4), Cr(2.9), Mn(4.7), Fe(15.3), Co(4.9), Ni(3.9)	P(1.3), Cl(2.5), Ti(1.0), Cu(1.9), Zn(1.3), Rb(1.2), Sr(0.9)
W10 – ***Endopleura uchi*** *Uxi*	Cl(4.3), K(13.9), Ca(62.4), Fe(7.8), Co(1.9)	P(1.1), S(0.7), Ti(1.3), Cr(1.0), Mn(1.1), Ni(1.4), Cu(0.7), Zn(0.5), Rb(0.5), Sr(0.7), Ba(0.7)
W11 – ***Hymenolobium modestum*** *Angelim-Pedra*	Cl(5.6), Ca(56.2), Cr(2.8), Mn(5.0), Fe(14.6), Co(3.9), Ni(3.4)	P(1.7), S(1.6), Ti(1.7), Cu(1.3), Zn(0.9), Rb(0.6), Sr(0.8)
W12 – ***Aspidosperma polyneuron*** *Peroba*	Cl(14.0), Ca(17.9), Cr(3.7), Mn(6.1), Fe(29.0), Co(8.3), Ni(7.1), Zn(4.3)	P(2.0), S(1.1), Ti(0.7), Cu(3.1), Rb(1.8), Sr(1.1)
W13 – ***Tachigali myrmecophila*** *Taxi*	Cl(13.7), K(14.3), Ca(12.2), Cr(4.3), Mn(9.3), Fe(21.7), Co(7.5), Ni(5.7), Cu(2.7)	P(2.3), S(0.9), Ti(1.5), Zn(1.5), Rb(1.3), Sr(0.9)
W14 – ***Vatairea spp.*** *Angelim-Amargoso*	Cl(3.3), Ca(59.5), Cr(2.2), Mn(2.8), Fe(13.9), Co(4.9), Ni(4.0), Cu(2.3)	P(1.2), S(0.8), K(1.2), Ti(0.8), Zn(0.9), Rb(0.5), Sr(1.6)
W15 – ***Andira legalis*** *Angelim-Coco*	P(2.5), Cl(7.4), Ca(57.5), Mn(5.7), Fe(11.7), Co(3.5), Ni(2.6)	S(1.6), Ti(1.6), Cr(1.8), Cu(1.3), Zn(0.9), Rb(0.7), Sr(1.1)
W16 – ***Ruizterania albiflora*** *Catauba*	Cl(15.5), Ca(18.8), Cr(4.1), Mn(11.3), Fe(23.7), Co(7.9), Ni(6.8), Cu(3.0)	P(2.3), S(1.3), Ti(1.9), Zn(0.9), Rb(1.7), Sr(0.9)
W17 – ***Clarisia racemosa*** *Guariuba*	S(2.2), Cl(5.0), Ca(36.6), Ti(4.7), Cr(3.3), Mn(7.1), Fe(20.2), Co(7.3), Ni(5.2), Cu(2.2)	Si(0.8), P(1.8), Zn(1.4), Rb(1.1), Sr(1.1)
W18 – ***Tabebuia cassinoides*** *Caxeta*	Cl(18.2), K(25.4), Ca(27.3), Cr(2.3), Mn(2.5), Fe(11.3), Co(3.2), Ni(2.3)	P(1.3), S(2.1), Ti(1.0), Cu(0.8), Zn(0.6), Rb(1.0), Sr(0.5)
W19 – ***Apuleia leiocarpa*** *Garapeira*	Cl(6.4), K(17.4), Ca(36.6), Cr(3.1), Mn(3.9), Fe(15.4),	Si(0.8), P(2.1), S(1.1), Ti(1.8), Cu(1.6), Rb(1.1),

	Co(4.4), Ni(3.4)	Sr(0.9)
W20 – *Protium sp.* *Breu*	Cl(5.6), K(6.6), Ca(27.5), Cr(2.1), Mn(29.1), Fe(13.0), Co(4.2), Ni(3.5)	Si(0.2), P(1.4), S(1.0), Ti(1.1), Cu(1.8), Zn(0.8), Rb(1.3), Sr(1.0)
W21 – *S/N* *S/N*	S(2.0), Cl(1.9), K(23.1), Ca(7.2), Mn(2.1), Fe(12.6), Co(3.4), Ni(3.1), Br(37.9)	Si(0.3), P(0.7), Ti(0.8), Cr(1.5), Cu(1.6), Zn(0.9), Rb(0.6), Sr(0.4)
W22 – *Pouteria sp.* *Abiurana*	S(7.3), Cl(8,8), K(26.1), Ca(21.7), Mn(7.5), Fe(13.3), Co(3.0), Ni(2.9)	Si(1.1), P(1.1), Ti(0.8), Cr(2.4), Cu(1.6), Zn(0.8), Rb(1.1), Sr(0.6)

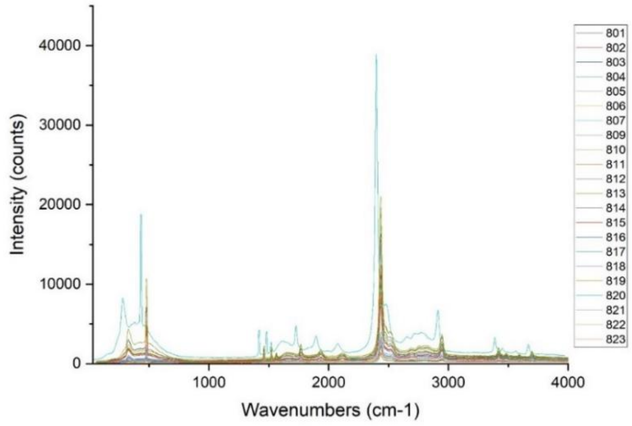

Figure 1 – Comparative Raman spectra of 22 wood species

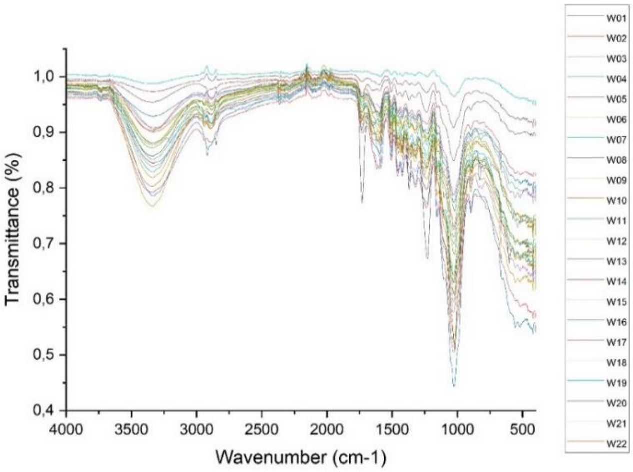

Figure 2 – Comparative FTIR spectra of 22 wood species

Despite belonging to the same biome, the wood species present variance in their elemental concentration presented in Table 1. Also, the ratio between major elements among species is different.

The most intense peaks in Raman spectra are: 333 (cellulose); 479 (lignin); 1460 (cellulose); 1523 (lignin); 1935 (lignin); 2435 (lignin); 2943 (cellulose, hemicellulose); 3419 (cellulose); 3697 (cellulose). Infrared most intense peaks are: 895 (cellulose); 1028 (cellulose); 1129 (cellulose, hemicellulose); 1264 (cellulose, hemicellulose); 1592 (lignin);

1651 (lignin); 1728 (hemicellulose); 3340 (cellulose, hemicellulose, lignin) (Agarwal, 1997; Makarem, 2019; Javier-Astete, 2023).

The spectra from Figures 1 and 2 show variance on intense peaks, which is essential to classify wood species.

4. Conclusions

The results of this pilot study indicate that the spectral techniques employed in this study can provide information to create a spectral database for the identification of wood species to be exported from Brazil. Also, from data evaluation, the authors observe that data from the 3 techniques should be used as compliment to ensure higher confidence. Nevertheless, data from more species is required to develop a reliable machine learning setup for this application.

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