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Chemistry

Evaluation of carbonized woods from Araucariaceae in different oxygen concentrations through thermogravimetry and scanning electron microscope

Avaliação dos lenhos carbonizados de Araucariaceae em diferentes concentrações de oxigênio por meio de termogravimetria e microscopia eletrônica de varredura

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ABSTRACT

Charcoal is one of the few lasting legacies of forest fires during thousands of years, representing a record of the dynamics of terrestrial biomes, as well as the characteristics of atmospheric oxygen throughout its ages. To understand climate change and fluctuations in atmospheric oxygen availability over time, the research used wood carbonization of *Araucaria columnaris* in thermal degradation (TGA) of 30% and 21% oxygen, and temperatures of 450°C and 600°C. These were then analyzed through Scanning Electron Microscopy (SEM) in different increases, observing the anatomy of the material in its three structural planes, and compared to bibliographies of studies developed in this area. The work highlighted a pattern in wood carbonization in both atmospheres, with significant changes in physical and chemical structure in all samples. The pyrolysis with oxygen and elevated temperatures, demonstrated fire aggressiveness, degrading with greater speed and intensity, observing the anatomical details that characterize gymnosperms. Thus, the studies aim at a greater understanding of the complex relationship between fire and the planet, and how climate change becomes essential for understanding the events of the future.

Keywords: Charcoal; Oxygen; Climate change; TGA; SEM

RESUMO

O *charcoal* é um dos poucos legados duradouros dos incêndios florestais ao longo dos milhares de anos, representando um registro da dinâmica dos biomas terrestres, assim como as características do oxigênio

atmosférico ao longo de suas eras. Com intuito do estudo sobre a compreensão das mudanças climáticas e das flutuações da disponibilidade de oxigênio atmosférico através dos tempos, a pesquisa utilizou a carbonização do lenho de *Araucaria columnaris* em termodegradação (TGA) com oxigênio de 30% e 21%, e temperaturas de 450°C e 600°C. Posteriormente, estas foram analisadas sob Microscopia Eletrônica de Varredura (MEV) em diferentes aumentos, observando a anatomia do material em seus três planos estruturais e comparados a bibliografias de estudos desenvolvidos nessa área. O trabalho destacou um padrão na carbonização do lenho em ambas as atmosferas, com alterações significativas na estrutura física e química em todas as amostras. A pirólise com oxigênio e temperaturas elevadas, demonstrou maior agressividade do fogo, degradando com maior rapidez e intensidade, observando nos detalhes anatômicos que caracterizam as gimnospermas. Sendo assim, os estudos visam um maior entendimento da complexa relação entre o fogo e o planeta, e como as mudanças climáticas se tornam essenciais para a compreensão dos acontecimentos do futuro.

Palavras-chave: *Charcoal*; Oxigênio; Mudanças climáticas; TGA; MEV

1 INTRODUCTION

Extinction and evolution have shaped the abundant life we see on our planet. This life owes its composition to forces existing on the earth throughout its history. Fire is a considerable source of disturbance (BELCHER, 2013). Reconstructions of paleo-fires provide us with information of the interaction of different environmental factors (climate and environment) with fire activity during past periods of history (HAMAD; JASPER; UHL, 2012).

Charcoal, produced from the incomplete combustion of vegetation, has paleoecological and paleoenvironmental characteristics, being considered a (paleo) indicator, preserving the source material anatomy, its chemical and biological structure (SCOTT, 2010). Thus, the study of charcoal provides us with information on the interactions between climate, fire ecology, and vegetation, interpreting such interactions under the climatic changes that occurred in the past (JASPER *et al*., 2011).

Studies by Scott and Glasspool (2006) revealed that over millions of Earth's years, there were fluctuations in atmosferic oxygen levels, influencing biological evolution, and playing an integral role in biogeochemical cycles. Once atmospheric oxygen reached an adequate concentration, fires could start occurring on the planet. This increase in O_2 concentration is conveniently coupled to diversification

in land plants (fuel), so since the beginning of the invasion of the soil by plants, fire not only had fuel, but also enough oxygen for combustion (BELCHER, 2013).

Higher concentrations of charcoal found in nature are related to the Carboniferous and Permian periods, even throughout much of the Cretaceous (BELCHER, 2013; JASPER *et al*., 2013; HAMAD; JASPER; UHL, 2012). On the other hand, there are few charcoal records originating from the First Triassic, First Jurassic, First Cretaceous, and from the Eocene to the Holeocene. Several of these charcoal records oscillations seem to be explained by variations in the oxygen concentration in the (paleo) atmosphere (BELCHER, 2013).

According to works by Berner (2006) and Scott and Glasspool (2006) there was a charcoal explosion as, in the Carboniferous and Permian geological periods, O_2 reached 30% of the atmosphere, occurring more specifically in the early Guadalupian epoch. Lower values were seen between the Silurian and Devonian; a range from 15% to 20% O_2 during the Cambrian and Ordovician periods. At the Permo-Triassic boundary, O_2 obtained a sharp drop from 30% to 15%. From the end of the Triassic to present days, the value increased rather continuosly.

Against the backdrop of concerns about the environmental changes that the world has been suffering from, the study of climate change becomes essential for us to understand the trajectory of life on Earth. Works related to climate fluctuations have been carried out to understand how the amount of atmospheric oxygen varied and influenced the Earth's fires over millions of years, using, for example, climate models capable of coherently reproducing paleoclimate situations, robustly simulating events that occurred in the paleoatmosphere. Also, studies related to paleo-fires seek a greater understanding of how fire has acted on our planet and how oxygen fluctuations have influenced it and its ecosystems (SCOTT; GLASSPOOL, 2006, 2010; BERNER, 2006; BELCHER, 2013; BERGMAN *et al*., 2004; DAHL *et al*., 2010; BELCHER; MCELWAIN, 2008).

In this context, the technique developed seeks the understanding of climate change from fluctuations in the amount of atmospheric oxygen. The experiment

evaluates the changes that occur during the carbonization process of wood from the Araucariaceae family, applying paleoenvironmental conditions to reproduce atmospheric conditions, simulating the period when the Earth had the greatest amount of oxygen available in the atmosphere, the Permian Period.

2 METHODOLOGY

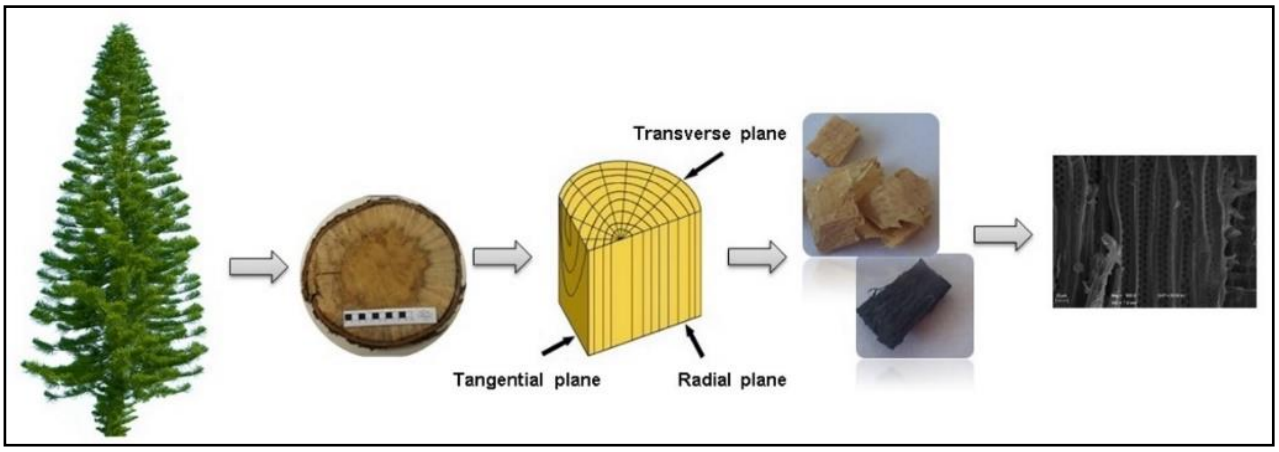
The objective of the study is the physical-chemical evaluation of results from the carbonization process of woods from a number of *Araucaria columnaris*, under different controlled gas atmospheres. In a practical sense, the technique aims to study the changes observed in varied oxygen concentrations in order to have a better understanding of the gas fluctuations that occurred in the paleoatmosphere.

The *Araucaria columnaris* wood was collected in the municipality of Colinas/RS (29º 32'28.84" S, 51º 50'28.35" L) in the form of a disk at 1.50 *m* high, according to the standards of phytosociological data surveys (GUREVITCH; SCHEINER; FOX, 2009), measuring 8 *cm* thick and from 18 *cm* to 35 *cm* in diameter. The studies and analysis were developed in the Scientific and Technological Park of Taquari Valley (Tecnovates) at UNIVATES.

2.1 Preparing the samples

The dry collected sample did not receive any chemical-physical treatment after its removal, and was used in natura in the experiments. The wood was cut radially, transversally and tangentially, to be visualized in scanning electron microscopy after pyrolysis, as shown in Figure 1.

Figure 1 – Steps used to study the artificial carbonization of wood



Source: Authors (2021)

2.2 Wood in natura pyrolysis by Thermogravimetry

The prepared samples were submitted to a Perkin Elmer thermogravimetric analyzer model TGA-4000, to carbonize the wood under various simulated atmospheric conditions. Sampling was performed in triplicate, using 20 mg (± 2 mg) samples, carbonized under 21% O_2 and 30% O_2 atmosphere, at a constant flow rate of 20 mL.min-1, heating at 25°C min^{-1} and room temperature (around 25°C).

The wood was heat treated in an atmosphere of 21% O_2, at 25°C up to 450°C and 25°C up to 600°C, as well as in an atmosphere of 30% O_2 with the same temperature ranges. The results are the average of each triplicate, expressed in percentage.

2.3 Anatomical analysis of charcoal

The charcoal anatomy was read from fractures made during the preparation of the samples, which were cut longitudinal transversally, tangentially, and radially. The three structural planes were carved with the aid of a stereomicroscope and a blade. After wood carbonization in the thermogravimetric analyzer, aluminum stubs were mounted using double-sided tape and the samples were submitted to metallization, as to cover non-conductive samples with gold ions (Au). Then, the

samples were observed with scanning electron microscopy (SEM - Carl Zeiss, model LS-10) at different magnifications, for 450°C and 600°C samples, for each specific cut.

The anatomical characteristics of the wood were evaluated, together with fire intensity, oxygen, and temperature variations. The cuts and analysis of wood characterisctics were performed according to the recommendations of the IAWA list for gymnosperm wood (IAWA, 2004).

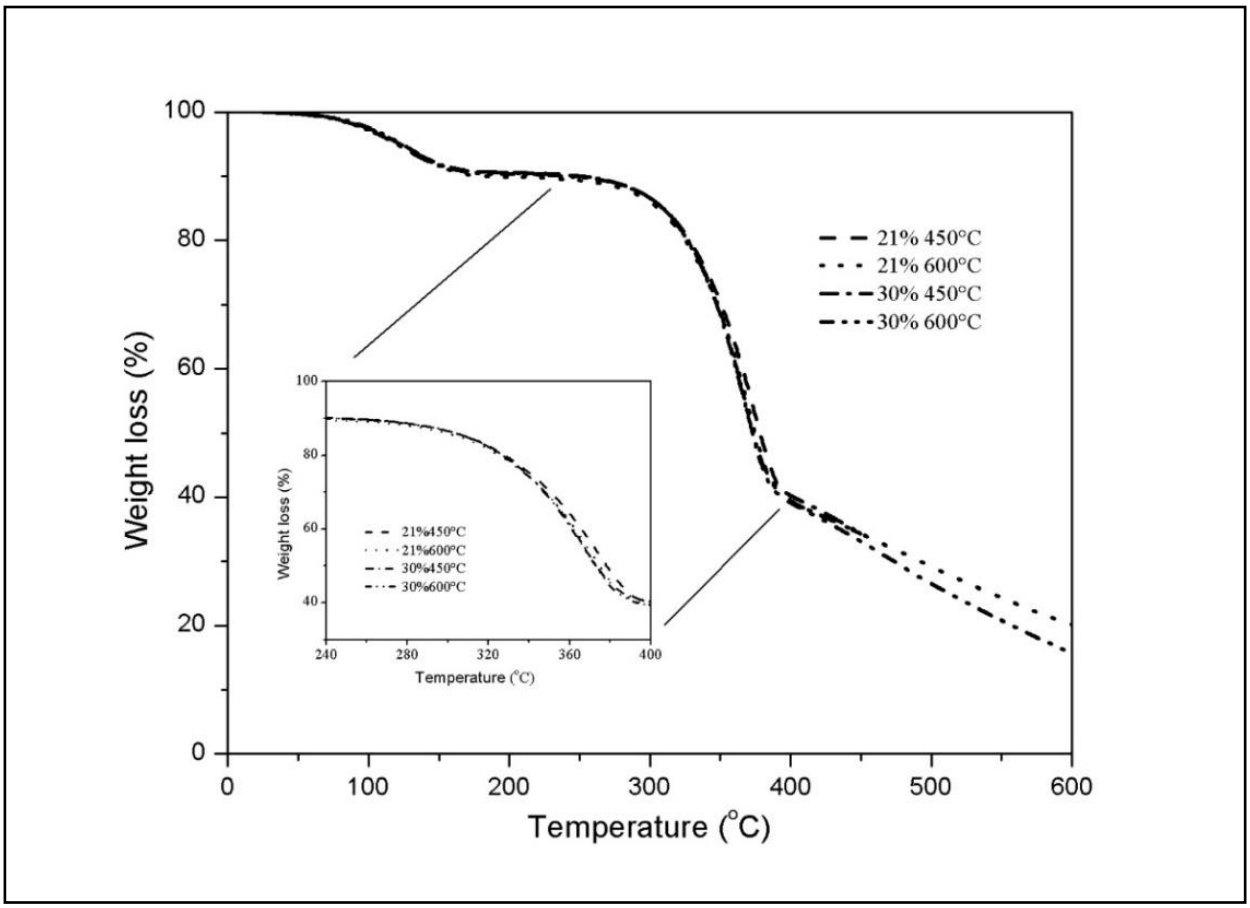
3 RESULTS AND DISCUSSION

Fossil charcoal traces occur at different geological levels around the world, from the Silurian to the Quaternary (JASPER *et al*., 2013; GLASSPOOL *et al*., 2004; SCOTT; GLASSPOOL, 2006). Understanding how changes in charcoal chemistry have occurred over time has the potential to reveal the combustion temperature of past fires and consequently provide insights into ecological impacts on the environment (GOSLING; CORNELISSEN; MCMICHAEL, 2019).

Macroscopic charcoal is formed from incomplete combustion of fuel under reducing conditions (IGLESIAS; YOSPIN; WHITLOCK, 2015). In temperate climate forests, ground surface fires range between 400°C and 600°C, while burning woody debris can exceed 700°C (PINGREE *et al*., 2016).

Softwoods, derived from conifers are predominantly composed of axial tracheids, which in turn are composed of 25% to 35% lignin, 37% to 45% cellulose and 20% to 25% hemicellulose (BRAADBAART; POOLE, 2008; MCKENDRY, 2007). The process of transforming wood into macroscopic charcoal can be analyzed once the behavior of the wood constituents that vary throughout the heating process are understood (COSTA, 2016), shown in Figure 2.

Figure 2 – TGA curves for charred wood, produced at different oxygen concentrations and heating rate of 25°C min^{-1}.



Source: Authors (2021)

The effect of increasing the temperature of organic material is expelling volatile materials that, when mixed with oxygen from the air, burn, providing heat for the reaction. The non-carbonized residues are called macroscopic charcoal or, simply, charcoal (SCOTT; DAMBLON, 2010).

In Figure 2 it is observed that the thermodegradation in different atmospheres present similar burning patterns. In these first moments of the transformation there are morphological changes in the structure of the samples, as well as loss of mass, with fragmentation and rounding of the materials, and their darkening (BRAADBAART; POOLE, 2008; LARA *et al*., 2017a; SCOTT, 2010).

Work developed by LARA (2017a) describes a change in coloration, with a decrease in the shape of the samples, making them more fragile and brittle. The

study also described that the highest mass loss occurred in the range from 200°C to 600°C, reaching the average of 84.74% and 2.61% for the range from 600°C to 1000°C.

The gradual increase in temperature initially generates a release of volatile materials, up to 175°C (PINHEIRO; FIGUEIREDO; SEYE, 2005), with samples degrading in very similar ways. Volatilization of the gases results in carbon skeleton condensation and aromatization, which leads to the formation of graphite-like layers in the wood (ASCOUGH *et al*., 2010).

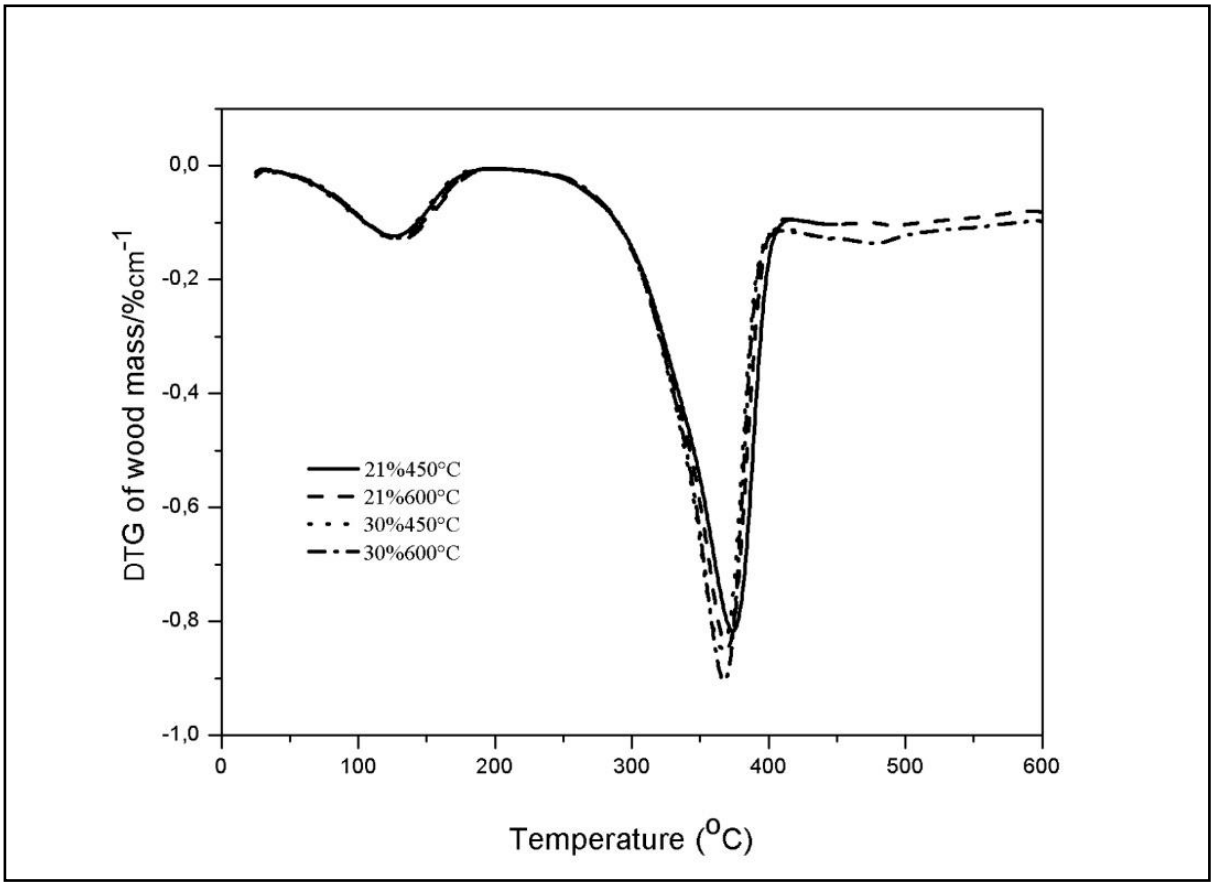
When passing through 340°C, we can observe that samples in 30% oxygen atmosphere have greater mass loss than the ones under 21% oxygen. Degradation of cellulose occurs between 300°C and 400°C (FIGUEROA; MORAES, 2009; PADILLA *et al*., 2019), while the degradation of hemicellulose happens between 250°C and 350°C, the latter representing about 20% to 30% of the dry mass of the wood. Hemicellulose is characterized by being a polymer composed of two classes of substances: xylans (typical of hardwoods) and glucomannans, characteristic of coniferous wood. It corresponds to approximately 20% of the dry wood constituent (FIGUEROA; MORAES, 2009; PEREIRA *et al*., 2013; BALLONI, 2009). At 400ºC the transformation of the wood into charcoal is practically complete (LARA *et al*., 2017b; FAO, 1985).

The degradation of lignin occurs over a wide temperature range, starting at 100 °C and up to temperatures near 900°C, peaking at 460°C, representing a more stable component (PEREIRA *et al*., 2016; PADILLA *et al*., 2019). Lignin is a compound of three-dimensional macromolecules, amorphous and branched. They present phenylpropane as the basic unit, joined by links of ether type (C-O-C) and carbon-carbon (C-C) type (PEREIRA *et al*., 2016; ROWELL *et al*., 2005).

The DTG results produce the first derivative of mass as a function of temperature, providing the speed of wood mass variation. Through them it is possible to analyze the beginning and end of each stage of the carbonization

process (PINHEIRO; FIGUEIREDO; SEYE, 2005). In Figure 3 the DTG curves are presented.

Figure 3 – DTG curves for carbonized wood, for different oxygen concentrations and heating rate of 25 °C min^{-1}



Source: Authors (2021)

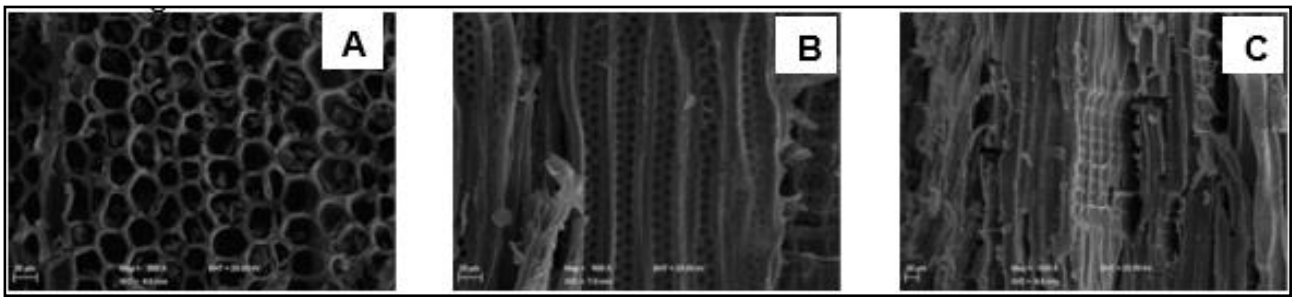
It is possible to observe that the samples submitted to 30% oxygen started degradating at a lower temperature compared to those submitted to 21%, showing sensitivity in relation to the atmospheric mixture. These variations reflected changes in the patterns of the old fires (BERNER *et al.*, 2003).

Around 600°C at 30% oxygen the samples showed greater burning power compared to the other samples, degrading cellulose and partially the lignin, which burns around 365°C, similar to the work of Padilha *et al*. (2019). According to studies by Scott and Glasspool (2006), observations on O_2 levels and fire in fossil records shows that when atmospheric oxygen is above 25%, fires become

widespread, which is especially the case for areas with high humidity due to the more common occurence of lightning strikes. Would oxygen be above 30%, fire activity would be distributed globally.

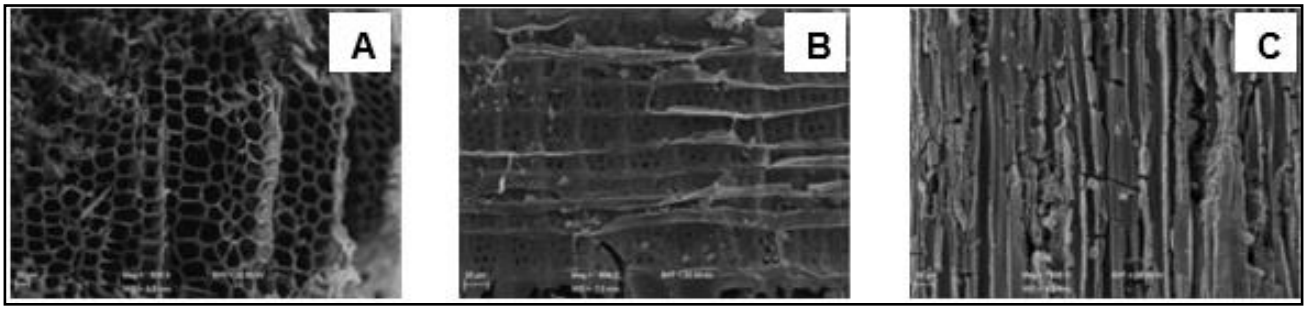
An important factor in the usefulness of charcoal, a paleoecological indicator, is the ability to preserve the anatomy of plants in environments where the material decays, having their botanical affinities visualized in a scanning electron microscope (CRAWFORD; BELCHER, 2014; SCOTT, 2000; 2010). In Figures 4 to 7 we can observe the samples of charred wood in an atmosphere in the percentages of 21% and 30% of O_2 in transversal, radial and tangential cuts in order to illustrate the differences and similarities that occur in pyrolysis.

Figure 4 – Wood samples carbonized in TGA at 21% O_2 450 °C, subsequently analyzed in FTIR and observed in a SEM.



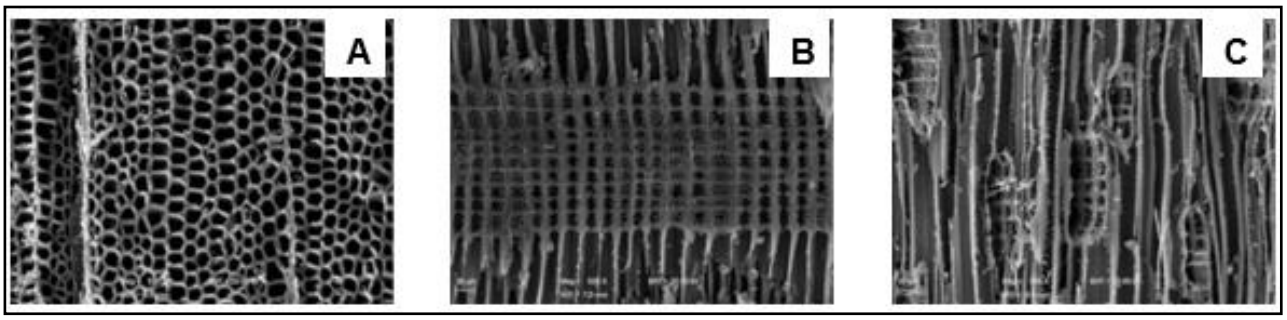
Source: Authors (2021)
In where: (A) Transverse section; (B) Radial section; (C) Tangential section

Figure 5 – Wood samples carbonized in TGA at 30% O_2 450 °C, subsequently analyzed in FTIR and observed in a SEM.



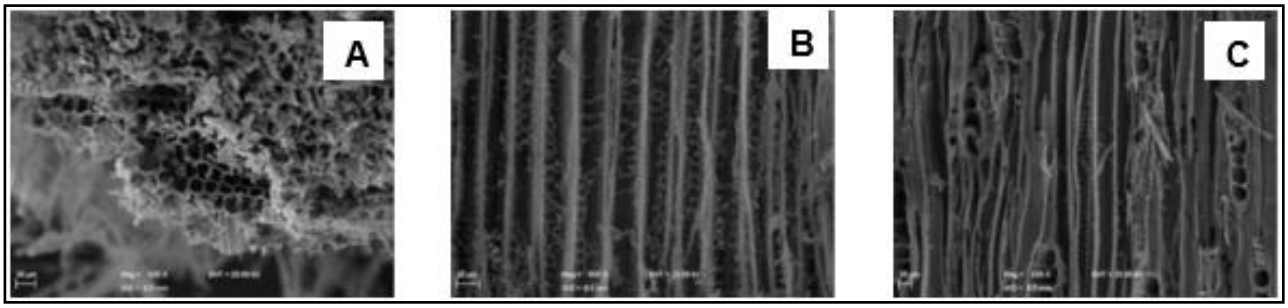
Source: Authors (2021)
In where: (A) Transverse section; (B) Radial section; (C) Tangential section

Figure 6 – Wood samples carbonized in TGA at 21% O_2 600°C, subsequently analyzed in FTIR and observed in a SEM.



Source: authors, 2021
In where: (A) Transverse section; (B) Radial section; (C) Tangential section

Figure 7 – Wood samples carbonized in TGA at 30% O_2 600°C, subsequently analyzed in FTIR and observed in a SEM



Source: Authors (2021)
In where: (A) Transverse section; (B) Radial section; (C) Tangential section.

During the carbonization process submitted to atmospheres of 21% and 30% of O_2 (Figures 4 to 7) the transformation of the wood into charcoal is observed, characterized by highly reflective, chemically inert, physically brittle samples with fragments correlated to the original wood of about 10 mm² (GLASSPOOL; EDWARDS; AXE, 2006; BELCHER, 2013; SCOTT, 2010).

In Figures 4C, 5C, 6C, and 7C, plant tissues that would normally exhibit a middle lamella and cell walls no longer show distinct layers, characterizing charcoal (BELCHER, 2013; SCOTT, 2010). The woody tissues (GLASSPOOL; EDWARDS; AXE, 2006) common to this conifer species are soft due to varying microscale kinetics, composed of tracheids. These supply nutrients and water for growth, connected by

bounded pits, parenchyma cells and, in several cases, resin channels (HAO; CHOW; LAU, 2020; PURSER; WOOLLEY, 1983).

The degradation of cellulose, a polymer present in greater abundance in the cell walls, releases a quantity of volatile gases, while the lignin becomes responsible for greater yield in the form of charcoal (ROWELL, 2005). Studies developed by Rowell (2005) show that component distribution may vary due to the species of wood, and that in the cell walls of a Scots pine, the middle lamella and the primary wall are composed mainly of lignin (84%) with a smaller amount of hemicelluloses (13.3%) and even less cellulose (0.7%).

Visual changes are observed in the carbonized wood samples in Figures 4A, 5A, 6A, and 7A, chemical structures are degradated, but still exhibit taxon-specific anatomical details (OSTERKAMP, 2017; SCOTT; GLASSPOOL, 2006). Thus showing interconnected cells in an intricate and predictable manner of an integrated system from root to branch. The transversal plane of the section (Figures 4A, 5A, 6A and 7A), radial plane (Figures 4B, 5B, 6B and 7B), and the tangential plane (Figures 4C, 5C, 6C and 7C) in which the structures of the wood are observed follow such patterns and show how this organization occurs (ROWELL, 2005).

In Figures 5 and 7, there is evidence that greater degradation occurs in an atmosphere with a higher O_2 index, which matches the graph in Figure 2. Shown in the radial sections of Figures 5B and 7B, vessels containing tracheids have greater loss in 30% O_2 atmospheres. Corrosion in the crossing fields, a common fracture pattern of the radial walls of the trachea, is present, as well as heavily macerated tracheids, in contrast to 21% O_2 atmosphere samples (Figures 4B and 6B).

At temperatures of 450°C, as seen in Figures 4B and 6B, the crossing fields are better preserved with areolate punctuations between tracheids characteristic of the structure of conifers that are more dense and morphologically resistant. Thus, it is necessary to defer greater firing energy in order to break the wood molecules (BRAADBAART; POOLE, 2008).

The rounded aspects observed in the cross sections of Figures 4A, 5A, 6A, and 7A, show intercellular spaces present in all samples. Greater protuberance is observed in their interior (Figure 7A), in the lumen, due to heavily macerated crossing fields, caused by changes in the cell walls due to rapid heating, with lignin being the main responsible for the exclusion of water during wood burning. (OSTERKAMP, 2017; ROWELL, 2005).

The performance of wood pyrolysis depends on factors such as wood properties, including moisture content, chemical composition, geometry, density, and external conditions, such as intensity of heat exposure and distance of flames from the wood surface (HAO; CHOW; LAU, 2020; BARTLETT; HADDEN; BISBY, 2019).

The tangential cut of Figures 4C, 5C, 6C, and 7C, are characterized by the removal of the bark from the trunk, presenting in 21% O_2 atmosphere (Figures 4C and 6C) fragments with punctuations inserted in the cross fields, besides visible homogenization of the cell wall, clearly defined uniseriate rays composed of parenchymatous cells and broken tissues. Pereira *et al*. (2016) describe that carbonization occurs in the tangential direction of vessel elongation (pores), changing from circular to oval with the burning of the wood. Thus, reducing the thickness of the cell walls of the fibers, leaving them with a glassy and brittle appearance.

Different degradation of wood in relation to the fire is observed in the studied samples. The carbonized wood submitted to 30% O_2 at 600°C has a greater loss of mass, reaching 84.28%, compared to 79.88% in 21% O_2 at 600°C. Samples submitted to 450°C burning have a similar degradation of 65.67% (30% O_2) and 65, 70% (21% O_2), demonstrating that the temperature has a great influence in the process of degradation and burning of chemical structures.

Thus, it can be observed that the loss in mass differs among the samples, in relation to 30% O_2 (Figures 5C and 7C), with a greater "power of degradation" on the atmosphere of 21%. However, the temperatures influence the decrease in mass, between 380 to 500ºC there is a reduction in gas emissions released, with the

production of acetic acid, methanol, tar and various condensable gaseous substances. The mass loss is of the order of 70% in relation to the original mass (FIGUEROA; MORAES, 2009).

At temperatures above 500°C, charcoal is the main residue, with the end of carbonization and beginning of gasification, obtaining a greater mass loss, of 80% cellulose, 95% hemicellulose, and 60% lignin (FIGUEROA; MORAES, 2009). Above 1,200°C, charcoal is no longer recognized (BRAADBAART; POOLE, 2008; THÉRY-PARISOT; CHABAL; CHRZAVZEZ, 2010).

The occurrence of fires in the past and the disposition of charcoal depend on atmospheric levels (KUBIK *et al*., 2020) perceived as frequency in the fossil record, the availability of fuel (wood) on the planet, which have had variations during history (KUBIK *et al*., 2020; GLASSPOOL; SCOTT, 2010; SCOTT; GLASSPOOL, 2006; HE; LAMONT, 2018).

Fossil charcoal records are being found throughout the Brazilian Gondwana, of the Permian Period, in the Paraná Basin as Milani and Ramos (1998), Tybusch and Iannuzzi (2008), Christiano-de-Souza and Ricardi-Branco (2015), Iannuzzi *et al*. (2007), Jasper *et al*. (2009), Milani *et al*. (2007), Bica (2014), Kubik *et al*. (2020). Addressing that atmospheric oxygen levels had risen to 30% in the atmosphere, the highest in Earth's history, triggering higher incidences of forest fires (BELCHER, 2013; GLASSPOOL; SCOTT, 2010; SCOOT *et al*., 2017).

Studies developed by Jasper *et al*. (2011) describe fossil charcoal of the Permian period from different localities, Candiota charcoal basin, Lubina Leão-Butiá, Bacalhau Faxinal, Morro do Papaléo, Quitéria outcrop, and Figueira Cidreira. The work links some observed anatomical characteristics of Araucarioides to other gymnosperms. Maximum carbonization temperatures in these studies range between 340°C and 600°C, characteristic of peatland fires (JASPER *et al*., 2011a; REIN *et al*., 2008).

According to the literature, fires range between 300°C and 600°C, being also the case for natural fires (ASCOUGH *et al*., 2010). Osterkamp *et al*. (2017) infers that

at 300°C the carbonization process is still incomplete for specimens of the genus Araucaria, while Lara *et al*. (2017b) presents similar wood degradation to the present study for samples of *Araucaria angustifolia*, *Araucaria bidwillii* and *Araucaria columnaris*. The latter obtained best results with temperatures ranging from 450°C to 600°C, serving as direct reference to the chosen pyrolysis and wood species choices.

For Kubik *et al*. (2020), the fires are based on measurements of fusinite (inertinite) reflectance and unsubstituted polycyclic aromatic hydrocarbon (PAH) concentrations. These occurred in drier seasons, with temperatures ranging between 375°C and 440°C, referring to surface fires. Work by Scott (2000) and Glasspool and Scott (2010) suggests that there is a connection between charcoal formation composed of inertinite and atmospheric oxygen levels.

The abundant evidence of wildfires in Gondwana demonstrates that burning occurred in various regions and time intervals during the Permian, corresponding to the transition from a cold climate to one with warmer periods (JASPER *et al*., 2013). It is estimated that the atmospheric O_2 level reached 30% in the in the Late Paleozoic - Permian, making the vegetation present highly flammable even under humid conditions, occurring large fires (SCOTT; GLASSPOOL, 2006; BERNER, 2006; JASPER *et al*., 2013; BELCHER *et al*., 2010).

Variations occurring in oxygen levels, climate, and vegetation have controlled fire for hundreds of millions of years (SCOTT, 2000). Studies provide crucial context for current fire/human/climate interactions and an opportunity to decouple climatic and human influences on fire regimes by examining topics such as climate history and contrasting demographic, cultural, and technological changes (MARLON *et al*., 2013).

The thermodegradation (Figure 2) of the wood samples occurred in a defined thermal event and obtained a similar burning pattern in both atmospheres, involving chemical and physical reactions dependant on temperature. The acceleration of the degradation curve was observed when a higher amount of

oxygen was available and a higher mass loss at elevated temperatures. Through these results, it is observed in the scanning microscopy analysis (Figures 4 to 7) the similarity of the action of fire in the wood degradation processes. With greater deconformity in the higher O_2 and temperature scenario, there is burning action of the degradative process of moisture, hemicellulose, cellulose and lignin decomposition.

Therefore there is a pattern of wood decomposition in the burning process, differing in some specific aspects and presenting a greater impact in atmospheres with 30% O_2. Regarding vegetation fires we must evaluate beyond the burning process, looking into the relationship between climate, weather, and the available fuels in the ecosystems (BOWMAN *et al*., 2009; FLANNIGAN *et al*., 2009).

The atmosphic structure is as vital as its chemistry, and the history of the climate is as relevant as the history of how the atmosphere evolved. During the Carboniferous and Permian, oxygen is thought to have increased to 30%, which made gigantism possible, with beetles the size of dogs and dragonflies the size of crows. About 150 million years ago there was a decrease in oxygen, stabilizing at 21%. This change accompanied by fire being paramount to the evolution of life (JONES; CHALONER, 1991).

There is a growing realization of the importance of charcoal in recording weathering, forest fire consequences, and interference with biogeochemical cycles. Considered in terrestrial models an indicator that restricts the limits of atmospheric oxygen, affecting the occurrence of vegetation fires (SCOTT; DAMBLON, 2010).

4 CONCLUSION

The developed studies analyzed in two different concentrations of atmospheric oxygen (21% and 30%) the pyrolysis of Araucariaceae wood at burning

temperatures of 450°C and 600°C. In conclusion the samples present significant changes in physical and chemical structure, being transformed into charcoal.

During thermodegradation, the carbonized wood underwent increasing degradation starting with hemicellulose, followed by cellulose, and finally lignin. However, samples submitted to a 30% O_2 atmosphere, had higher 'burning power' than in a 21% O_2 atmosphere, staring to lose mass at lower temperatures.

The firing temperature also influenced the degradation process, showing greater aggressiveness in samples under 600°C than at 450°C. However, the qualitative characteristics of the original wood remain intact, while the quantitative characters such as cell size and wall thickness change.

After heating the wood, the anatomical structures did not change significantly, still exhibiting taxon-specific anatomical details, with major differences in relation to the firing temperature and similarities with fossil charcoal from the Permian period of the Paraná Basin.

The results obtained express that fire temperatures and the disposition of atmospheric oxygen influence the degradation of forest firewood. Thus, contributing to a greater understanding of the complex relationship between fire and the planet and how climate change becomes essential for understanding the events of the future.

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