Agr. Acad. J., v. 6, n. 2, Mar/Apr (2023)

Contents available at Scilit

Agrarian Academic Journal

agrariacad.com

doi: 10.32406/v6n2/2023/84-100/agrariacad

Activated bamboo charcoal and açaí waste to remove contaminants – a review. Análise comparativa entre carvão ativado de bambu e de resíduos do açaí para remoção de contaminantes – uma revisão.

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Abstract

Activated charcoal is a product based on bio-based materials and residues with specific porosity to act as a filtering compound, both to remove color and impurities of liquids. They are produced from physical and/or chemical process, after carbonization, through the activation of molecules. The present paper aims to identify the current perspectives and characteristics of activated charcoals and, sequentially, compare the potential of bamboo and açaí plants to treat contaminants in water. Thus, different positive characteristics were identified for both bio-based resources. Bamboo and açaí can be economically and technically viable materials to be converted into activated charcoal as a way to mitigate the environmental impacts on the water.

Keywords: Charcoal. Bioproducts for filtration. Removal. Environmental impacts.

Resumo

O carvão ativado é um produto à base de materiais de base biológica e resíduos com porosidade específica para atuar como composto filtrante, tanto para remover a cor quanto as impurezas dos líquidos. São produzidos a partir de processo físico e/ou químico, após carbonização, através da ativação de moléculas. O presente trabalho tem como objetivo identificar as perspectivas e características atuais dos carvões ativados e, sequencialmente, comparar o potencial das plantas de bambu e açaí para tratar contaminantes na água. Assim, foram identificadas diferentes características positivas para ambos os recursos de base biológica. O bambu e o açaí podem ser materiais economicamente e tecnicamente viáveis para serem convertidos em carvão ativado como forma de mitigar os impactos ambientais na água.

Palavras-chave: Carvão. Bioprodutos para filtração. Remoção. Impactos ambientais.

1. Introduction

The contamination and degradation of ecosystems by polluting gases, agricultural and industrial waste, organic residues and chemical products have been widely approached by the modern society (CHEN et al., 2020; KISHOR et al., 2021).

These pollutants result in environmental disequilibrium and drastically reduce the potable water sources (HYNES et al., 2020) In addition, about 12 to 20 tons of waste from numerous anthropic activities has been improperly discarded in ecosystems, significantly impacting the environment (ZHOU et al., 2019).

The disposal of waste, whether organic or inorganic, generates the need to use techniques or technologies to remove pollutants, which, even in small amounts, can pose a risk to human health (PIQUET; MASTELLI, 2022). An alternative source to mitigate environmental impacts includes the conversion of residues, usually incorrectly discarded, in biomass into adsorbents as a way to reduce this unwanted pollution through a low cost and easy access solution . The most traditional adsorbents include activated carbon, biomass, silica gel, clays, and zeolites (ANI et al., 2020; ALKATHIRI et al., 2020).

Activated carbon is a material with a highly developed surface area and specific porosity, being widely requested due to the extensive raw materials, diversified production methods, high chemical and thermal resistance, and adsorption and catalytic properties (SERAFIN et al., 2022).

Due to the physicochemical properties of carbon materials, they are often considered as adsorbents for many gaseous and liquid substances (KAIPPER et al., 2001; DWIVEDI et al., 2004; PÉREZ-CADENAS et al., 2013; OUZZINE et al., 2019), catalysts (KHALIFEH; GHAMARI, 2016; MLODZIK et al., 2016; WRÓBLEWSKA et al., 2017; GAMAL et al., 2019), storage processes (SRENSCEK-NAZZAL et al., 2013; ZHU, ZHENG; 2016), supercapacitors (SAKA et al., 2020), and others.

The decomposition of biomass by thermochemical processes generates activated carbon, where the dominant method, called physical activation, includes two stages: carbonization of the organic materials and subsequent activation by partial gasification of the carbonaceous materials with a gaseous agent such as steam, carbon dioxide, among others. The chemical activation is used on a smaller scale, because the material is mixed with a suitable chemical reagent, $ZnCl_2$, KOH, H_3PO_4 and NaOH, and subjected to a heat treatment (SERAFIN et al., 2022).

These three reagents initially mentioned are frequently used to obtain activated charcoal from chemical activation, as they confer better surface areas compared to physical activation (LUXEMBOURG et al., 2007; KAGHAZCHI et al., 2010). The adsorption process is among the main popular techniques to remove contaminants using adsorbents, which consists of a porous solid material with high mechanical resistance and chemical inertia to enable efficient decontamination (BELMABKHOUT et al., 2016; SALEH et al., 2018).

In practice, carbon utilization began with pre-historic period through the use of charcoal, extending its applications to exploit physicochemical, adsorptive, structural and biocompatible properties of different forms of carbon, that is, from elemental- to bio-based materials. Thus, the modern versions of activated charcoals are biologically derived from wood, bamboo, peat, coconut shells, bones and numerous by-products from agriculture and silviculture activities (MARSH; RODRÍGUEZ-REINOSO, 2006; MORE; BOKROS, 2006).

Bamboo is considered a versatile plant in reason of plural advantages related to economy and environment. Due to its characteristics of fast growth, short rotation, high productivity and abundance of bio-based resources, bamboo positively presents many morphological aspects such as wall thickness and high biomass productivity. These benefits make this bioresource promising for the production of active charcoal (FANG et al., 2018; VAN-DAM et al., 2018).

Alternatively, agriculture has provided numerous options of fruits, vegetables and grains to be consumed ‘in natura’ or converted into industrialized products. But the industrialization process usually generates by-products and residues. In this way, the accumulation of this unused material can become a potential environmental problem, above all, if any waste is discarded incorrectly.

For example, açaí, a fruit of açaí palm (*Euterpe oleracea* Martius), stands out in the Amazon region to the detriment of other plant resources for its opulence and importance as an easy access food for local populations, being that this native plant provides fruits and hearts of palm for the Brazilian agroindustry. But only 17% of açaí seeds are used to obtain pulp for juices and ice-creams, generating 83% of waste (SATO et al., 2020). In this way, further studies are demanded to reuse this residue in order to mitigate impacts caused by the irregular deposition of açaí seeds.

Therefore, this paper aims to identify characteristics and properties of activated charcoal and compare the potential of bamboos and açaí, using a bibliographical review, to highlight their uses as activated charcoal to treat contaminated water.

1.1. Bamboo

Bamboo is a fibrous plant of the Gramineae or Poaceae family, Bambusoideae subfamily, which is classified as a giant grass capable of producing food from the shoots and wood from the lignified culms. This plant has 45 genus and 1300 species worldwide (PEDRANGELO et al., 2020; RUSCH et al., 2022). Specifically, bamboos are globally available, found in the tropical, subtropical and temperate regions of Asia, Oceania, Africa and America. More than 400 species are found only in Latin America, with 258 species native to Brazil and 12 endemic genera. Many species may be easily introduced in different regions, as they have a wide variety of ecological niches. Due to fiber, bambusoidae has excellent physical-mechanical characteristics and growths three times faster than other plants. According to Nunes et al. (2021), bamboos may reach their maximum heights in less than a year, in an average of 30 meters in height. In addition, this plant has easy regeneration, being able to offer continuous harvest and produce for more than 30 years without the need for replanting.

Bamboo species have suitable characteristics as a fuel for thermal power generation, as they have visible potential for several industrial sectors, above all, to replace eucalypt chips due to similar quality (MARAFON et al., 2019).

More than three thousand uses are estimated for this material, which include food, craft, energy, infrastructure and housing construction, medicine and materials for industry such as fibers and textiles, composites and panels, charcoal, ethanol, and biomass for bioenergy (RUSCH et al., 2022; XIAO et al., 2010; BARRETO et al., 2019; BAZ et al., 2019; GAUSS et al., 2019; MUNIS et al., 2018; RUSCH et al., 2020; NARESWARANANINDYA, 2021).

Bamboo provides significant amount of biomass, high specific mass, short harvest cycles and high material productivity in the order of 40 tons per hectare/year. These characteristics explain the use of this bioresource for bioenergy (FANG et al., 2018; VAN-DAM et al., 2018; BAZ et al., 2019).

Its use as biochar is also justified by the diversity of species and morphology. In Brazil, *Bambusa* and *Phyllostachys* genera represent the most economically important species (CAMPOS et al., 2016).

Another important aspect to be highlighted is the high presence of silica in bamboo, especially in the in the outermost layers (bark), being responsible for the protection of culms against impacts and action of organisms. Silica acts as an adsorbent in the application to remove contaminants from soil and water, increasing the potential of this plant (ZANONI et al., 2019).

1.2. Açaí

The açaí palm (*Euterpe oleracea* Martius) is a native plant to the Brazilian Amazon, which is among the main plants that provide livelihood through food production for local populations being that its natural dispersion is perceptibly identified in the Pará state (RAIOL et al., 2016).

Açaí fruit is a small, round and dark drupe, whose content includes a pulpy mesocarp and a seed with a reduced embryonic axis and considerable endosperm tissue, spherical in shape, representing 75% of the mass of the complete fruit (ALMEIDA et al., 2017). In the maturity, this fruit is rich in cellulose, about 53.2%, and 12.6% of hemicellulose and 22.3% of lignin and, with that, this vegetable composition is convenient for the bioenergy production (LIMA et al., 2021).

As the fruit market is entirely driven by the production of pulp, which ranges from 5 to 15% of its volume of each fruit, the amount of waste from this processing is visibly high and, therefore, this residual biomass may be utilized from different ways such as bioenergy, charcoal, and craft (CORREA et al., 2019).

Considering the relevant potential of Brazil for agricultural production, there is a large generation of agro-industrial waste and by-products (SATO et al., 2020). Pará state is responsible for 95% of the national production, with approximately ten thousand only in the metropolitan region of Belém (ADEPARÁ, 2017).

The residue from fruit exploitation consists mainly of açaí seeds, which still do not have an adequate economic destination, as they are discarded in landfills, dumping grounds and in rivers, without treatment, which cause environmental impacts and losses of potential of this waste (LOPES et al., 2022). Greater use of the açaí waste must mitigate the impacts through alternatives for different sectors (SATO et al., 2020).

1.3. Activated charcoal

Activated charcoal is a carbonaceous material with a porous structure and high surface area, whose characteristics allow efficient adsorption and multiple production forms with high content of carbon and low content of organic matter (PIQUET; MASTELLI, 2022; NASCIMENTO, 2019).

This product is formed from carbonaceous materials with a disorganized crystallographic structure, through randomly distributed microcrystals, with a high surface area (500 - 1500 m²/g), a wide variety of functional groups (carboxylates, carbonyls, hydroxyls and amines) and a pore size (<1 - 100 nm). These properties offer an excellent ability to adsorb numerous molecules (SOUSA et al., 2021; PALLARÉS et al., 2018; MASOUMI; DALAI, 2020).

The stability of activated carbon is a highly desired characteristic, being influenced by the contents of lignocellulosic components in the biomass, that is, cellulose, hemicellulose and lignin (SATO et al., 2020). Cellulose is used to adsorb water, metal ions, organic substances and dyes, while lignin is responsible for the ion exchange of the material and the thermal stability of the biomass (GUL et al., 2021).

Therefore, lignocellulosic residues have been increasingly studied, as they structurally contain components that confer adsorbent quality and promote the adsorption of different materials (PIQUET; MASTELLI, 2022).

The activated charcoal originates from the thermal decomposition using the process of slow oxidation of carbon through oxidizing agents such as steam and carbon dioxide under controlled conditions between 400º C and 900º C. The activation may also occur chemically through the carbon impregnation with chemical products (NaOH, $ZnCl_2$, KOH, H_3PO_4), which promote dehydration, poly-condensation and gasification reactions at lower temperatures than those required for physical activation. Due to high costs of commercial activated charcoal, alternative adsorbents with similar adsorption efficiency have been studied, above all, those solutions produced from agricultural and extractivism activities (ALKATHIRI et al., 2020; ALAM et al., 2020; REZA et al., 2020; ACHOUR et al., 2021; KANNAUJIYA et al., 2023).

1.4. Adsorption

The adsorption process is a physical-chemical separation method, in which the porous structure of an adsorbent material has the ability to retain organic or inorganic pollutants on its surface, that is, adsorbates. The phenomenon occurs when the adsorbate molecules come into contact with the adsorbent, creating a force field due to their imbalance on the solid surface, attracting and retaining these molecules at the adsorption sites (SOUZA et al., 2021).

The adsorbate-adsorbent interaction is classified into physisorption and chemisorption. The interaction between adsorbate and adsorbent surface is associated to the Van Der Waals forces in the physical adsorption, being relatively weaker as long as the adsorbate molecules exchange or share electrons with the adsorbent surface in the chemical adsorption, creating stronger bonds (AZEVEDO, 2015).

Numerous factors influence the adsorption process such as adsorbate characteristics, adsorbent properties (surface area, pore distribution and presence of functional groups) and conditions of temperature and power of hydrogen (NASCIMENTO et al., 2020). The adsorption process may be superior to other residue treatments when simplicity, effectiveness and operation are considered (MULLER et al., 2019), as it has advantages related to a rapid operation with high selectivity to remove color, odor and other contaminants (ACHOUR et al., 2021).

1.4.1. Influencing factors of adsorption

The particle size and absorbate polarity are characteristics that strongly influence the adsorption rate, since a polar species have more affinity for the solvent or for the adsorbent, depending on the polarity. The physicochemical nature of the adsorbent is also a factor that influences the adsorption, since its capacity and rate depend on the surface area, porosity, functional groups of the adsorbent, electronegativity and the nature of the precursor material (NASCIMENTO et al., 2020). Therefore, porosity, surface chemistry, potential of hydrogen, and temperature factors are commented briefly in this subtopic.

The structure of pores is the main physical property to characterize the activated charcoal and, even with the intense utilization of micropores in research, the macropores also play an important role related to the adsorvate path in the micropores – found mostly inside the particle.

Pores may be classified both by their sizes and their shape. About size, macropores have diameters greater than 50 nm, mesopores present diameters from 2 to 50 nm, micropores are between

2 to 0.8 nm, and those diameters smaller than 0.7 nm are known as ultramicropores. The shapes include open and transport conditions, whose last option is featured by the material transfer from an end to other (SCHULTZ, 2016; YAHYA et al., 2015).

The functional groups in the charcoal structure define the acidic or basic character of its surface. Oxygenated groups are more present in the charcoal structure due to the abundance in its elemental constitution, which presents a considerable level of acidity. The potential of hydrogen (pH) may affect the surface load of adsorbent and influence the adsorption kinetics. When pH is changed, hydrogen and hydroxyl ions are strongly adsorbed and the adsorption of other ions is affected by the pH of a solution. The variation in pH affects the adsorption by the dissociation of functional groups at active sites on the adsorbent surface (SOUZA et al., 2021).

Temperature may directly affect the adsorption velocity. In general, an increase in kinetic energy is caused by a rise in temperature, increasing the mobility of the adsorbate species. This temperature elevation still affects the solubility and chemical potential of the adsorbate, causing changes in the adsorption capacity. In addition, it may unclog pores in the adsorbent structure, allowing the penetration of larger molecules of adsorbate (NASCIMENTO et al., 2020).

2. Results and discussion

After a thorough prospection, papers were selected and the results related to the approach about bamboo and açaí charcoal were clearly listed in the Table 1.

Therefore, eleven papers were found and presented in detail to emphasize their relevant aspects, which were related to:

- Paper source (authors);
- Adsorbent under analysis (biomaterials);
- Adsorbate in use (chemical molecules);
- Methodology and main parameters (temperature, time, power of hydrogen, carbonization process, and activation process);
- Adsorbate characteristics (surface area, pores, contents, and removal);
- Efficiency of process (capacity and performance).

According to the information identified in the Table 1, it was evident that both activated carbon precursor biomasses undergo structural transformations of physicochemical processes in order to optimize the adsorptive potential – this situation is consistent with the literature review, where both temperature and agents for activation can cause the decomposition of characteristic components of plant biomass such as lignin, cellulose and hemicellulose, as they promote the development of the basic structure of charcoal (FUKUTOME et al., 2017; AMRAN; ZAINI, 2021).

Still, it is essential to consider that activated carbons have a wide variety of surface functional groups and therefore depend on the precursor material and the evaluation method, which is why it is important to identify all groups, since they are responsible for determine the surface properties of activated carbon (YORGUN; YILDIZ, 2015). Also, it is important to emphasize that the sites are not always available, due to possible obstructions, demanding the analysis of ash content, humidity and volatile materials. Low values for ash and moisture contents make precursors suitable for producing adsorbents. High moisture content is related to the storage of samples in humid environments or in the production process (OZDEMIR et al., 2014), and depending on the solvent used in the adsorption, part of the ash can be extracted, which contaminates and changes the pH solution (YAKOULT et al., 2015). So, the ash content of activated carbon may be an important parameter for adsorption.

Table 1 - Data about documents towards bamboo and açai charcoal.

Source[a]	Adsorbent	Adsorbate	Methodology	Adsorbate Characteristics	Efficiency
Brito (2020)	Bamboo charcoal (*B. Tuldoides*)	Unstudied	Slow pyrolysis with three temperatures and three heating rates, and chemical activation with zinc chloride	37 to 47% yields, 60 to 75% fixed carbon contents, high ash content, low surface area, and increase in surface after activation (850 m^{2}g^{-1})	High capacity to remove contaminants
Santana et al. (2019)	Bamboo charcoal (*B. vulgaris*)	Methylene blue and phenol	Carbonization (500º C, 1 h and 1,67º C.min^{-1}), and activation (800º C, 10º C.min^{-1}, 1 h)	22% yield, 82% fixed carbon content and surface area (857 m^{2}g^{-1})	558 mg.g^{-1} phenol and 299 mg.g^{-1} methylene blue
Santos et al. (2015)	Cattle bones and bamboo charcoal	Methylene blue	Batch system using 6 h for bones and 24 h for bamboo for a pH 5	Not informed	96% (15 mg.g^{-1}) bones and 55% (9 mg.g^{-1}) bamboos
Paixão et al. (2021)	Bamboo charcoal (*G. weberbaueri*)	Faecal coliforms	Pyrolysis with 3 temperatures (400, 500 and 600º C) for 2.5 h, chemical activation (HCl, CH_3COONa) and synthesis with oxide and nanoparticles	400º C charcoal and chemically activated charcoal revealed an abundantly porous surface (60 nm diameter of holes) for samples activated with CH3COONa	Efficient for water purification for consumption, removing fecal coliforms
Ip et al. (2009)	Commercial charcoal, bone, turf, and bamboo	Reactive Black 5 dye	Bamboo charcoal and activated bamboo charcoal with phosphoric acid	Chemically activated charcoal showed greater surface area (2123 m^2.g^{-1}) than non-activated charcoal (1400 m^2.g^{-1}) of bamboo	545 mg.g^{-1} (bamboo), 447 mg.g^{-1} (activated bamboo), 176 mg.g^{-1} (commercial charcoal), 157 mg.g^{-1} (bones), and 7 mg.g^{-1} (turf)
Santana et al. (2018)	Bamboo charcoal (*B. vulgaris*)	Methylene blue	Double physicochemical activation with vapor and phosphoric acid (500º C, 1h)	Surface area of 685 m^2.g^{-1} with predominance of acid groups in its surface with porosity creation	301 mg.g^{-1} of dye
Lopes et al. (2022)	Activated carbon of açaí	Acid yellow 17 dye	Pyrolysis at 500º to 700º C temperatures and pH 7	High adsorptive capacity, being promising for the effluent treatment	67 e 99% of removal
Almeida et al. (2021)	Activated acai biochar	Caffeine	400º C temperature, pH 7, and K_2CO_3 solution	High adsorption, being up to 60% superior to literature	177 mg.g^{-1}
Gonçalves Jr et al. (2021)	Chemically modified Açaí	Cd (II), Pb (III), Cr (III)	30º to 900º C temperature, pH 3 to 7, and three activations	Chemical modification of açaí increased the metal ions removal	Cd^{2+}: Fresh CA (73,2%), CA H_2O_2 (74,7%) and CA H_2SO_4 (71,2%) Pb^{2+}: CA H_2O_2 (78,8%)
Sousa et al. (2021)	Activated carbon of açaí seeds	Malachite Green Basic Dye	Binary solution (H_3PO_4 and NaOH), 450º C temperature	Activated charcoal with good adsorption for both solutions, being efficient to remove dye	112 mg.g^{-1} (H_3PO_4), and 669 mg.g^{-1} (NaOH)
Souza et al. (2018)	Activated carbon of açaí seeds	Yellow 2, red 1, blue 26, and green 1 dye	Chemical activations (HNO_3 and H_3PO_4), 450º C temperature and pH 7	Activated charcoal with H_3PO_4 were more efficient to remove dyes due to structure of pores	Basic green 1 (100%)

[a]data obtained from the several sources.

About the characterization of the adsorbent, it is recommended to analyze the surface area such as size, volume, distribution of pores and functional groups present on the surface of the porous material, as activated carbon with low surface area is undesirable, especially for adsorption studies (LIU et al., 2018). Therefore, adsorbents with high surface and small particle size are more effective in the adsorption (KAYA; UZUN, 2021). However, significant improvements of activated carbon are evidenced in the literature due to chemical activations in the surface area and volume of pores, because this chemical process has the ability to increase the porosity of activated charcoal, in addition to affect surface chemical properties (functional groups, hydrophobicity and polarity) (TAN et al., 2017).

In the literature, most materials studied after chemical activation revealed increases in their surface areas, due to the predominance of meso- and micro-sized pores, focusing on the effects of the use of different activating agents and the comparison between them (LIEW et al., 2018; BRANDÃO et al., 2020; MEDHAT et al., 2021).

Temperature is another parameter that has a direct influence on the adsorption process, where it determines not only the efficiency of the adsorptive capacity, but also the type of activation, whether physical or chemical (KAYA; UZUN, 2021).

The increase of temperature in the pyrolysis changes physical, chemical, morphological and spectral properties of the activated charcoal, especially in the surface area and volume of pores (IBERAHIM et al., 2022). The higher the temperature, the greater the amount of pores developed and, indirectly, the higher surface area (HOSSAIN et al., 2011; PENG et al., 2011). But there is a drop in the performance at temperatures above 450º C. This fact is explained by the large volumes of ash that block the activated carbon pores and hamper the adsorption process (LEE et al., 2014; TOMCZYK et al., 2020).

The functional groups on the surface of activated carbon are influenced by the preparation method, whose acidic properties are caused by the existence of carboxyls, lactones and phenols, making the adsorbent more hydrophilic and decreasing the power of hydrogen, which concludes that the functional groups are related to the reactivity and adsorption properties of carbon (RODRIGUES et al., 2020). Thus, activated carbon with an acidic interface favors the removal of anionic compounds and, when faced with a basic profile, the adsorption of cation occurs. As the surface of activated carbon has a greater amount of acidic functional groups, its interface is more acidic. When the pH is lower than pHpcz, the adsorbent has the ability to adsorb anions due to the presence of positive charges (ZHANG et al., 2019).

Regarding the adsorption kinetics, it was observed that most of the papers described in Table 1, the pseudo-second order described most of the experiments. This finding indicates that the rate of adsorption is controlled by the chemisorption mechanism, that is, it is an irreversible reaction with bonds through the transfer of electrons between the adsorbate and the surface area. In contrast, higher concentrations can generate competition among the solute molecules (DRWEESH et al., 2016; SILVA et al., 2019).

The studies whose kinetics were adjusted to the pseudo-first order model described the reaction in the first stages, in addition to the adsorption rate of the adsorbate being directly proportional to the amount of free sites in the physisorption mechanism (SILVA; SIMONI, 2018; CHAHINEZ et al., 2020).

A better kinetic adjustment can also be mentioned through intra-particle diffusion, where the initial adsorption is fast and spontaneous, followed by a gradual phase and, later, slow removal occurs, in which there is a reduction in speed as the concentration decreases. and the reduction of available sites. Another notation was the Elovich’s kinetic model, which refers to a good fit for removing pollutants in aqueous solutions, in real solids, through mechanism of chemisorption (SILVA et al., 2021; OLIVEIRA et al., 2018).

Thus, from the perspective based on two sources widely available in Brazil, bamboos and açaí seeds, there is a relevant potential to convert these bioresources into activated charcoal as a way to develop alternatives of manufactured solutions in line with the greater use of different residues from agroforestry sectors. This reuse situation meets the suggestions led by Araujo et al. (2022) as assertive strategies to promote bio-based products towards the bioeconomy using resource and industry synergies to reduce waste and intensifying new products and markets.

There is a long way to go before it becomes materialized, as Lima et al. (2021) identified that the Brazilian industry still requires studies and technologies to standardize and improve the production methods, inserting chemical processes, as the national scenario have been dominated by the physical activation in reason of its lower cost. In Brazil, this process may be scientifically and technically supported by the development of technologies and characterizations of new bio-based resources, as this nation offers compatible institutions and careers as Forest Engineering and Timber Industrial Engineering in Brazil as evidenced by Araujo et al. (2021) in their study.

3. Conclusions

From the foregoing, it is possible to conclude that the use of low-cost biomasses evince positive characteristics to be used as alternative adsorbents for the removal of various pollutants, including different colored substances, being economic and viable options to mitigate impacts on the ecosystems, especially water environments. Yet, it was observed that the type of contaminant in the solute can influence the choice between the adsorbent, for example, activated charcoals.

Due to the wide variety of biomasses, an expansion in research is suggested for a better understanding of the relationship between different bioresources and their desorption capacity for the removal of pollutants.

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Recebido em 10 de outubro de 2022
Retornado para ajustes em 17 de janeiro de 2023
Recebido com ajustes em 22 de maio de 2023
Aceito em 19 de junho de 2023