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Effects of pyrolysis temperature on the final properties of biochar: A literature review

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Abstract

Biochar produced from biomass pyrolysis is a promising agent for wastewater treatment, soil acidity correction and energy-generating fuel. This review addresses recent studies on the synthesis and applications of biochar, with a focus on evaluating the impact of pyrolytic temperature on the physicochemical properties of biochar. Among its applications, adsorption is one of the most relevant methods due to its cost-benefit. The change due to variation in the pyrolytic temperature in the specific area and surface functional groups, cation exchange capacity (CEC), ash content, carbon content and electrical conductivity (EC) of the biochar were studied and influenced by pyrolysis temperature. . These properties are of great value for optimizing the adsorption capacity of biochar, as the review also consider the ideal pyrolytic temperature for producing biochar with greater yield and efficiency. Based on the review, it can be concluded the relevance of the pyrolysis temperature in the characterization of biochar and its influence on its adsorption capacity.

Keywords: Biochar; Temperature; Pyrolysis; Adsorption.

1. Introduction

Biochar is obtained by thermal treatment of organic waste or biomass. One of the ways to produce this biochar is through pyrolysis, which occurs under hypoxic conditions or in the absence of oxygen. Biochar is a carbonaceous material, and plays fundamental roles in correcting soil acidity, generating energy and adsorbing [1]. Biochar has become an interesting object of study, due to its possibility of being used as an alternative to reduce the emission of gases responsible for the greenhouse effect, such as CO_2 resulting from the natural decomposition of waste, and being a low-cost bioadsorbent, added to a high surface area and incorporation of functional groups on the surface [2]. Adsorption using biochar is seen positively, in addition to being more economically viable and an environmentally sustainable possibility, it presents good adsorption performance on toxic pollutants [3]. The physicochemical characteristics of biochar, specific surface area, pore size distribution, type and quantity of functional groups on the surface are dependent on the conditions and methods of pyrolysis, in which temperature is one of the most important parameters in the formation of biochar [4].

Pyrolysis temperature is a key to biochar production. Temperature conditions can vary from lower (< 450°C), moderate (450-550°C) and high (550°C >) values, in which each temperature range can affect the properties of biochar [5]. At lower temperature ranges, biochar presents higher yields and above this range, the production of bio-oil, gas and ash stands out [5,6]. The textural properties and surface functional groups of biomass are modified due to thermal degradation in the pyrolysis process, which affects other properties such as cation exchange capacity (CEC), ash content, carbon content and electrical conductivity (EC) [5,7].

Studies report the use of biochar from different biomasses to understand the ability of biochar to remove aqueous nitrate [8,9,10,11], these showed positive results and the need to explore more about tools to optimize the adsorptive process. Regarding the studies, both the pyrolysis temperature and the type of biomass were the main parameters responsible for the biochar yield and its adsorption capacity.

Therefore, the present work aims to carry out a literature review on the effect of pyrolysis temperature on the final properties of biochar. Added to this, explore the optimization of the biochar adsorptive process, evaluating the change in physicochemical characteristics such as morphology, existence of surface functional groups, cation and anion exchange capacity, specific surface area and elemental composition.

2. Materials and methods

The methodology of this work was developed through a bibliographic review. In order to filter the best content for the revision, the journal relevance criteria were used through the impact factor, as well as the free availability of the journal on the web and whether the research vehicle was reliable. Therefore, the articles were searched in the main scientific databases, such as CAPES journals, Scientific Electronic Library Online (SCIELO), ScienceDirect and Google Scholar.

The filter used was based on publications from the last 7 years (2017-2024), as well as key words such as "Biochar", "Temperature", "Pyrolysis", in English "Biochar", "Temperature" and "Pyrolysis". Abstracts, conference papers, monographs and theses were excluded from the review.

The investigation of articles was carried out through general searches in the databases already mentioned. After the search, filters were applied in order to avoid works that were not consistent with the desired topic, or that were out of date, thus optimizing the time and quality of the review.

3. Biochar production temperature and its properties

Studies by Liang, J. et al, 2020 report the influence of varying pyrolytic temperatures (300 to 750 °C) on the final characteristics of biochar from maize straw biomass. The temperature of 750 °C presented the lowest yield among the other temperatures, as well as higher values of pH, carbon and ash content, which can be explained by the high degradation of surface functional groups. The study concluded that the optimal temperature for biochar production from maize straw biomass is 700 °C, this result could be found due to its better surface area and a possible higher adsorptive value. At a temperature of 750 °C there was a significant decrease in the adsorption capacity of biochar. This effect can be explained by the damage of the fine pore structure of biochar due to high temperature [12].

Park et.al, 2019 study the ideal pyrolytic temperature for $NH_3 - N$ removal. Temperatures in the range of 300-600 °C were tested. The increase in electrostatic repulsion, caused by the dissipation of cationic functional groups, impairs the removal of $NH_3 - N$. Of all the temperatures investigated, 500 °C showed the best specific surface area [7].

The concept of direct proportionality between temperature and surface area has some limitations. Islam et.al, 2022 explains that high temperatures (above 600 °C) can harm the surface area of biochar from Moringa Oleifera leaves biomass due to the formation of macropores. There is also a possibility of high ash contents (produced on a larger scale due to high temperatures) obstructing the micropores, thus interfering with their adsorptive activity [13].

Roshan et.al, 2023 carried out a meta-analysis bringing together various data on the properties of biochar correlated with different pyrolytic temperature ranges. Higher temperature ranges (greater than 550 °C) showed greater surface areas and better adsorption capacities. Other parameters were analyzed, such as CEC (cation exchange capacity) and EC (electrical conductivity). At elevated temperatures, the electrical conductivity of biochar is higher, this can be explained due to the increase in carbon content. The cation exchange capacity decreased in higher temperature ranges, due to the dissipation of functional groups such as carboxylates and hydroxyls. The best temperature range was the moderate range (450-550 °C) [5].

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5. References

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