



CAPÍTULO 14

Physicochemical Characterization of Pineapple Peel (*Ananas comosus*) for Use as a Biosorbent

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ABSTRACT

This study analyzed the physicochemical characteristics of pineapple peel (*Ananas comosus*) aiming at its utilization in possible technological applications. The methodology involved collecting the biomass in Capanema, Pará, followed by drying, grinding, and analyses including moisture content, ash content, real and bulk densities, porosity, volatile matter, fixed carbon, pH and point of zero charge. The results indicated a moisture content of 15.16%, an ash content of 4.52%, a real density of 0.60 g/cm³, a bulk density of 0.45 g/cm³, a porosity of 25%, a volatile matter of 75.2%, a fixed carbon content of 20.22%, an acidic pH of 4.8 and a point of zero charge of 5.9. Thus, it is concluded that pineapple peel has potential as a low-cost biosorbent, contributing to the utilization of agro-industrial waste and sustainable solutions in effluent treatment.

Keywords: Pineapple peel. Biosorption. Agroindustrial Waste. Physicochemical characterization. Environmental Remediation.

Introduction

Pineapple (*Ananas comosus*), which belongs to the Bromeliaceae family, is a tropical fruit native to South America, initially found in Paraguay, Brazil and Argentina. This fruit is characterized by its sweet and acidic flavor, spiny skin, green crown, and pulp with white or yellow coloration, depending on the stage of ripeness. It is widely consumed both fresh

and in the food industry, where it is mainly used for the production of juices, jellies and sweets (Souza et al., 2017).

During the processing of the fruit, however, only the pulp is utilized, while other parts, such as the peel, stem and crown, are often discarded. According to the Food and Agriculture Organization of the United Nations (FAO, 2023), Brazil is the fourth largest producer of pineapples in the world, with around 3.9 billion tons per year, significantly contributing to the agricultural Gross Domestic Product (GDP). According to the Brazilian Institute of Geography and Statistics (IBGE, 2023), the country produced approximately 1.6 billion tons on a cultivation area of 63.9 thousand hectares. Among the states that stand out the most in production are Pará 21.5%, Paraíba 19.1% and Minas Gerais 10.0%.

The pineapple peel, like other plant-based residues classified as biomass, has a lignocellulosic layer composed of cellulose, hemicellulose, and lignin. These components give the biomass structural and functional characteristics that make it promising for applications such as the biosorption of pollutants in aqueous media. According to Silva (2011), pineapple peel has a high fraction of hemicellulose (40%), in addition to 30% cellulose and 5% lignin, which favors its use in environmental processes and the production of low-cost, high-performance alternative methods.

In recent years, biosorption has emerged as a promising alternative for the removal of organic pollutants in wastewater and industrial effluents, due to its high efficiency in contaminant removal and low operational cost (Ribas & Silva, 2023). In this sense, agro-industrial residues, such as sugarcane bagasse and pineapple peel, have shown great potential as biosorbents in the removal of contaminants from aqueous solutions. The recent study by Rodrigues (2019), which investigated the use of pineapple peel as a biosorbent, demonstrated the ability to remove up to 88% of herbicide in aqueous medium, highlighting its effectiveness for environmental remediation purposes.

Given this scenario, this study aimed to analyze the physicochemical characteristics of pineapple peel with the goal of using it as a potential biosorbent. The proposal is based on the valorization of agro-industrial waste, contributing to the reduction of environmental impacts and encouraging low-cost sustainable solutions.

Materials and Methods

The drying, grinding and physicochemical analysis processes of the biomass used were carried out at the Laboratory of Engineering and Environment of the Federal Rural University of the Amazon, Capanema Campus.

Raw Material

The pineapple (*Ananas comosus*) used in this study was obtained from the open market in the municipality of Capanema, located in the state of Pará (Figure 1). For the preparation of the material, the pineapple peel was carefully separated from the pulp and subjected to a drying process. At first, the material was exposed to sunlight for a period of 24 hours. Next, it was transferred to an air-circulating oven, where it remained for another 24 hours at a temperature of 50°C. After the completion of this procedure, the material was ground in a cutting mill and stored for future analyses.

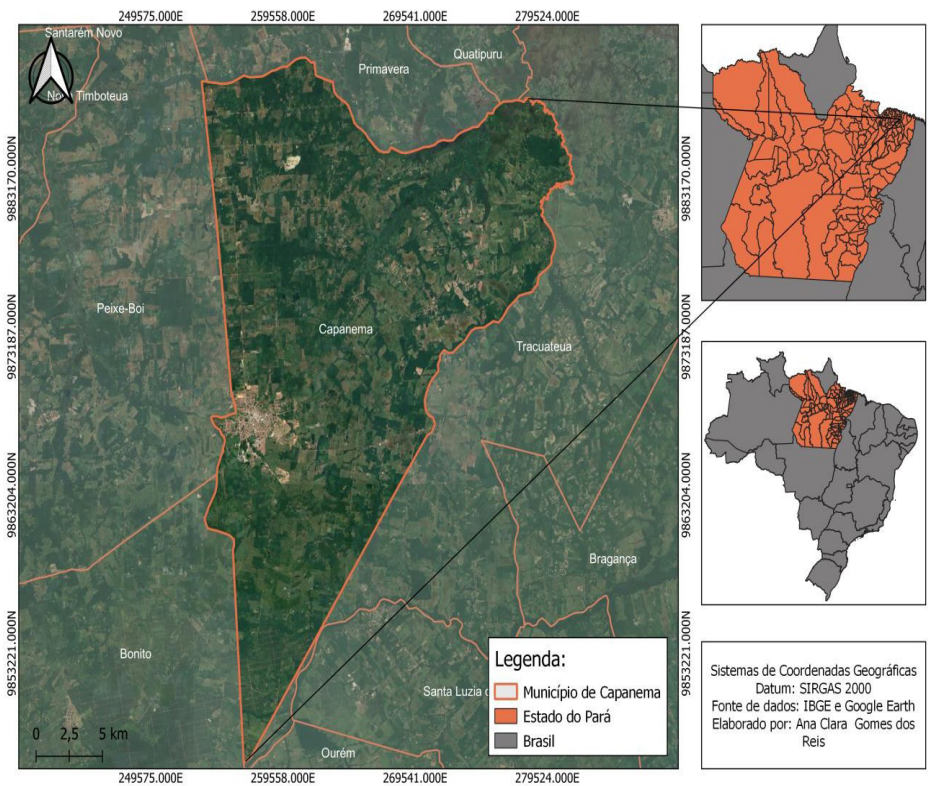


Figure 1 Map of the Location of the Pineapple Collection. Source: Reis (2026).

Physicochemical Characterization of Pineapple Peel Longitudinal, Transverse and Fruit Width Diameters

Measurements were obtained using a vernier caliper (Zaas Precision), and the results were expressed in centimeters (cm).

Mass of the Fruit, Peel, Pulp, and Crown Leaves

The whole fruit and individual parts were weighed separately using an analytical balance, and the results were expressed in grams (g).

Peel Thickness

Peel thickness was measured using a vernier caliper (Zaas Precision), and the results were expressed in centimeters (cm).

Moisture Content

The moisture content analysis was carried out according to Silva et al. (2015) and calculated using Equation 1.

$$MC\% = \frac{w_w - w_d}{w_w} \times 100 \quad (1)$$

Where:

MC: Moisture content (%);

Ww: Wet weight (g);

Wd: Dry weight (after 24 h) (g).

Bulk Density

This analysis was conducted in accordance with the ASTM D2854-09 standard (Graituito et al., 2007; Namane et al., 2005) and Equation 2 was used for its quantification.

$$BD = m/v \quad (2)$$

Where:

BD: Bulk density (g/cm³);

m: Mass of biomass (g);

v: Occupied bulk volume (cm³).

Real Density

The tests for determining the real density were conducted in accordance with the NBR165 Standard and calculated following the ASTM D2854-09 Standard (Ramos, 2005), using Equation 3.

$$RD = ma/[ma - (mw - mw')] \quad (3)$$

Where:

RD: Real density (g/cm³);

ma: Mass of biomass (g);

mw: Mass of the volumetric flask + water + biomass (g);

mw': Mass of the volumetric flask + water (g).

Porosity

With the values obtained from the real and bulk density equations, it was possible to determine the porosity percentage of the material, following the ABNT NBR 9165 Standard (ABNT, 1985) and Equation 4.

$$\phi = \left[1 - \left(\frac{BD}{RD} \right) \right] \times 100 \quad (4)$$

Where:

Φ: Porosity (%);

BD: Bulk density (g/cm³);

RD: Real density (g/cm³).

Ash content

For the determination of ash content, the procedure used was the official method ASTM Standard Method Number E1755-01 "Standard Method for the Determination of Ash in Biomass", and for the calculation of the ash content, Equation 5 was used.

$$A (\%) = \left(\frac{m_3 - m_1}{m_2 - m_1} \right) \times 100 \quad (5)$$

Where:

A: Ash content (%);

m₁: Mass of empty crucible (g);

m₂: Mass of crucible + initial sample (g);

m₃: Mass of crucible + ash (g).

Volatile Matter

For the determination of the volatile matter, the methodology of the ASTM D3175-07 Standard (ASTM INTERNATIONAL, 2007) was used, and the quantification was carried out using Equation 6.

$$VM (\%) = \left(\frac{m_2 - m_3}{m_1} \right) \times 100 \quad (6)$$

Where:

VM: Volatile matter (%);

m_1 : Mass of the initial sample (g);

m_2 : Mass of crucible + initial sample (g);

m_3 : Mass of crucible + final sample (g).

Fixed carbon

The fixed carbon was determined according to the ASTM D3172-89 Standard (ASTM INTERNATIONAL, 1989), using Equation 7.

$$FC (\%) = 100 - (AC + VM) \quad (7)$$

Where:

FC: Fixed Carbon (%);

AC: Ash content (%);

VM: Volatile matter (%).

pH

The pH analysis in suspension was carried out using 50 mL beakers, where 3 g of biomass and 30 mL of distilled water were first added in a 1:10 (solid:solution) ratio (Singh et al., 2010). The pH was determined using the Tekna T-1000 pH meter.

Point of Zero Charge

The analysis was conducted according to the method proposed by Regalbuto and Robles (2004), using seven pH values (4, 5, 6, 7, 8, 9 and 10). In each flask, 50 mL of distilled water and 0.05 g of biomass were added, and the pH levels were controlled using hydrochloric acid and sodium hydroxide, both with a molar concentration of 0.1 M. The resulting suspensions were subjected to agitation in a Luca-22 Shaker incubator for 24 hours at a temperature of 30 °C. The construction of the graph and the determination of the point of zero charge were obtained using the Origin software.

Results

Physicochemical Characterization of Pineapple Peel

Table 1 presents the results of the physical analyses of the pineapple peel.

Table 1 Results of the Physical Analyses of Pineapple.

Physical Analyses	Results ± Standard Deviation (SD)
Length (cm)	39,25 ± 0,55
Longitudinal diameter (cm)	19,25 ± 0,55
Transverse diameter (cm)	8,90 ± 0,14
Total fruit mass (kg)	1,19 ± 0,09
Peel mass (kg)	0,18 ± 0,01

Source: Authors (2025).

According to Rocha et al. (2020), the pineapple of the Pérola variety has an average length of 31.05 cm, a diameter of 14.86 cm, and a total mass of 1.35 kg. In the study by Berrili et al. (2014), the fruits of the same variety showed a length of 16.1 cm, a diameter of 10.5 cm, and a mass of 1.04 kg. In comparison to the results obtained in the present study, it is observed that the analyzed fruits showed greater total length and mass similar to other studies. The differences in the results may be related to the cultivation conditions, soil, climate and the stage of ripeness at the time of harvest. Moreover, the way the measurements were conducted in each study can also influence the results.

Moisture content

The moisture content, on average, was 15.16% ± 0.48. In a similar study, Miranda (2015) found a content of 13.03% ± 0.35 for the dehydrated pineapple peel in an oven. Souza et al. (2011) observed an even lower value of 12.63% ± 0.0017 when using the peel in the production of cereal bars subjected to irradiation. The differences between the results may be related to the drying time, the preparation conditions, and even the variety of the fruit. Even with similar methods, small factors can influence the final moisture content of the peel.

Bulk Density

The bulk density obtained in the analysis was 0.45 g/cm³ ± 0.04. The study on the pyrolytic process of pineapple biomass, developed by Santos (2018), presented a value of

0.47 g/mL $\pm$ 0.009 for the bulk density of pineapple peel, determined from the average of the obtained results. In comparison with the value found in this work, it is observed that the results are similar, indicating consistency between the studies.

Real Density

The real density showed a result of 0.60 g/cm³ $\pm$ 0.016; however, no results for comparison of this biomass were found in the literature.

Porosity

The porosity obtained for the pineapple peel was 25%, based on the values of bulk density and real density. However, no specific data was found in the literature that would allow a direct comparison with this result.

Ash Content

The ash content obtained for the pineapple peel was 4.52 g $\pm$ 0.23. This value represents the amount of minerals present after the organic matter is burned. In comparison with other studies, this result showed a value close to that presented by Erkel et al. (2015), where the ash content found was 4.43 g $\pm$ 0.03, while Miranda (2015) obtained a value of 4.24 g $\pm$ 0.47 for pineapple peel.

Volatile Matter

The volatile matter of pineapple peel obtained in this study was 75.26%, indicating that the biomass has a high proportion of volatile organic material, susceptible to thermal decomposition. In comparison, the value reported in the literature by Albuquerque et al. (2018) for the same biomass was 73.88%, which suggests that the material analyzed in this study has a slightly higher potential for pore formation and the release of organic compounds, essential characteristics for applications in adsorption processes and other environmental purposes.

Fixed Carbon

The fixed carbon of the pineapple peel, obtained in this study, was equal to 20.22%, according to the value reported by Albuquerque et al. (2018), which reported a value of 20.26% for the pineapple peel.

pH

The pH obtained for the pineapple peel was 4.8 ± 0.00 . This result indicates that the residue has an acidic character, which is common in plant-based materials and can directly influence its application as a biosorbent. In comparison with other studies, Oliveira (2021) reported a pH of 3.88 ± 0.18 , Da Costa (2007) recorded 3.98 ± 0.02 and Nunes et al. (2017) obtained a pH of 4.18 ± 0.00 , agreeing with what is found in the literature.

Point of Zero Charge

The point of zero charge obtained in the study was 5.9 as observed in Figure 2.

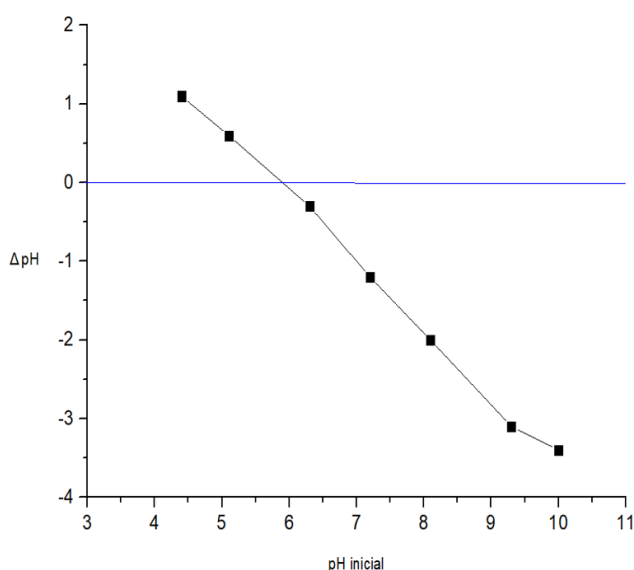


Figure 2 Graph of Point of Zero Charge. Source: Authors (2025).

The result found for the point of zero charge indicates that, under conditions of pH below 5.9, the surface of the material tends to exhibit a positive charge, as it favors the adsorption of anions, while at pH above this result, the surface becomes negative, facilitating the adsorption of cations.

When compared with the literature, it is observed that the highest PCZ values were found in biocarbon from pineapple waste, as reported by Santos (2018), who obtained a PCZ result of 9.6 and by Fu et al. (2016) who identified values above 9 at different pyrolysis temperatures. The difference can be explained by the fact that the biochars undergo

thermal treatment processes that modify their surface properties, in contrast to the raw material used in this study.

conclusion

The physicochemical characterization of pineapple peel (*Ananas comosus*) indicated that the material exhibits properties compatible with plant biomass used as biosorbents in environmental studies.

The results obtained in the study for the analyses of moisture content, ash content, bulk and real densities, porosity, pH, and point of zero charge demonstrate characteristics that may favor their application in adsorption processes.

The point of zero charge indicated the acidic nature of the material, a factor that can influence its interaction with different adsorbates, depending on the environmental conditions. Although the adsorption capacity was not evaluated in this study, the characterization carried out provides important support for future stages of the research.

Thus, pineapple peel therefore has potential for use as a biosorbent, contributing to the repurposing of agro-industrial waste and the development of environmentally sustainable alternatives.

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