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Research Article

Proximate analysis and characterization of African-balsam (*Daniel oliveri*) sawdust as a sustainable adsorbent material

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Abstract: This study presents the proximate analysis of African-balsam *(Daniel oliveri)* sawdust to characterize its physicochemical properties for potential use as an adsorbent. The analysis revealed a pH of 5.79±0.4, indicating a slightly acidic nature. The moisture content was determined to be 10.26±0.6%, ash content at 3.03±0.40%, volatile matter at 1.73±0.03%, and fixed carbon at 84.97±0.06%. Compared to other adsorbents such as rice straw, Daniella ogen, Mangifera indica, and Azadirachta indica, African-balsam sawdust exhibits notably low volatile matter content and a high fixed carbon content, suggesting its suitability for applications requiring high carbon stability. These findings highlight the potential of African-balsam sawdust as a cost-effective and efficient adsorbent material for environmental and industrial applications.Furthermore, the study emphasizes the environmental relevance of converting abundant lignocellulosic waste into value-added materials, thereby contributing to waste minimization and sustainable resource utilization. The relatively low ash and moisture contents further enhance its applicability by reducing preprocessing requirements and improving adsorption efficiency. The results also suggest that African-balsam sawdust could serve as a precursor for activated carbon production with desirable porosity and surface characteristics. Overall, this work provides a foundation for future investigations into adsorption kinetics, isotherm modeling, and large-scale application of African-balsam sawdust in wastewater treatment and environmental remediation processes.

Keywords: Adsorbent, Physicochemical, statistical analysis, agricultural biomass

1. Introduction

The escalating demand for sustainable, cost-effective materials for environmental and industrial applications has spurred significant interest in utilizing agricultural and forestry by-products as adsorbents. Biomass-derived materials, such as sawdust, offer immense potential due to their abundance, renewability, and suitability for applications in pollutant removal, wastewater treatment, and carbon sequestration (Ghaedi et al., 2022). African-balsam (*Daniel oliveri)* sawdust, a by-product of the timber industry in tropical regions, emerges as a promising candidate due to its lignocellulosic composition and favorable physicochemical properties. Characterizing such materials through proximate analysis is essential to evaluate their suitability as adsorbents and to optimize their performance in diverse applications (Oladipo et al., 2023).

Proximate analysis serves as a fundamental method for determining key physicochemical properties of biomass, including pH, moisture content, ash content, volatile matter, and fixed carbon. These parameters provide critical insights into the material's chemical stability, thermal behavior, and adsorption potential. For instance, a high fixed carbon content indicates a stable carbon structure, desirable for adsorbent applications,

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while low volatile matter suggests reduced thermal degradation (Adebayo et al., 2021). The pH of the material influences its interaction with pollutants, particularly in aqueous systems, where surface charge governs adsorption efficiency (Wang et al., 2024). Additionally, moisture and ash contents inform the material's storage, handling, and processing requirements, impacting its practical utility (Kumar & Singh, 2023).

Previous studies have characterized various biomass-derived adsorbents, such as rice husk, Daniella ogen, Mangifera indica, and Azadirachta indica, through proximate analysis, revealing significant variations in their properties that influence their applicability (Jin & Chen, 2007; Elehinafe et al., 2019a, 2019b, 2019c). Recent research has further explored lignocellulosic biomass for adsorption, with studies on bamboo sawdust and palm kernel shell demonstrating high fixed carbon content and low ash, enhancing their efficacy for heavy metal and dye removal (Oladipo et al., 2023; Zhang et al., 2025). However, limited research has focused on African-balsam sawdust (*Daniela Oliveri*), despite its widespread availability in tropical regions and potential as a low-cost adsorbent.

This study aims to characterize African-balsam sawdust powder through proximate analysis, determining its pH, moisture content, ash content, volatile matter, and fixed carbon. The results are compared with those of other biomass-derived adsorbents to assess its relative potential for environmental applications. By elucidating the physicochemical properties of African-balsam sawdust, this research contributes to the growing body of knowledge on sustainable adsorbent materials and supports the valorization of underutilized biomass resources. The findings are expected to guide the development of African-balsam (*Daniela Oliveri*) sawdust as an efficient, eco-friendly material for adsorption-based processes in environmental remediation and industrial applications. In recent years, increasing environmental regulations and the growing awareness of pollution control have intensified the search for alternative adsorbent materials that are not only effective but also economically viable. Conventional adsorbents such as activated carbon, although highly efficient, are often expensive and require complex regeneration processes. This has led researchers to explore low-cost biomass materials as viable substitutes. Agricultural residues and forestry by-products have gained considerable attention due to their biodegradability, low cost, and widespread availability.

Lignocellulosic materials, in particular, possess functional groups such as hydroxyl, carboxyl, and phenolic groups, which play a crucial role in adsorption mechanisms. These functional groups enhance the interaction between the adsorbent surface and pollutants through mechanisms such as ion exchange, complexation, and physical adsorption. Consequently, materials like sawdust not only provide structural advantages but also chemical reactivity that supports adsorption processes.

Despite the promising characteristics of many biomass materials, there remains a gap in the comprehensive evaluation of lesser-studied species such as African-balsam. Given its abundance in tropical regions and its current underutilization, it is essential to explore its physicochemical properties in detail. Such investigations can promote its inclusion in sustainable material development and support circular economy initiatives by converting waste into valuable environmental remediation resources.

2. Materials and methods

The proximate analysis of African-balsam (*Daniela Oliveri*) sawdust powder was conducted to determine its physicochemical properties, including pH, moisture content, ash content, volatile matter, and fixed carbon. The experimental procedures followed standard protocols for biomass characterization, ensuring accuracy and reproducibility. The methodology is detailed below, outlining the sample preparation, analytical techniques, and equipment used.

2.1. Sample Collection and Preparation

African-balsam sawdust was collected from Kofar Ruwa local sawmill in Kano state, Nigeria. The sawdust was obtained as a by-product of timber processing to ensure consistency in particle size and composition. The collected sawdust was air-dried under ambient conditions (25–30°C) for 48 hours to reduce initial moisture content and prevent microbial degradation. The dried sawdust was then sieved using a 250-μm mesh sieve to obtain a uniform particle size, ensuring homogeneity for subsequent analyses. The sieved sawdust was pulverized into a fine powder using a laboratory-grade ball mill to enhance surface area and facilitate accurate measurements. The prepared powder was stored in airtight polyethylene bags at room temperature to prevent moisture reabsorption until analysis.

2.2. Proximate Analysis

The proximate analysis was performed following standardized methods, including those outlined by the American Society for Testing and Materials (ASTM) and other established protocols for biomass characterization (ASTM D1762-84, 2013). All experiments were conducted in triplicate to ensure precision, and the average values were reported. The specific procedures for each parameter are described below.

2.3. Determination of pH

The pH of the African-balsam sawdust powder was measured using a digital pH meter (Hanna Instruments, HI-2211). A 5 g sample of the sawdust powder was mixed with 50 mL of deionized water in a 100-mL beaker to create a 1:10 (w/v) suspension. The mixture was stirred continuously for 30 minutes using a magnetic stirrer to ensure thorough interaction between the sample and water. The suspension was allowed to settle for 10 minutes, and the supernatant was filtered using Whatman No. 1 filter paper. The pH of the filtrate was measured at 25°C, with the pH meter calibrated using standard buffer solutions (pH 4.0, 7.0, and 10.0) prior to measurement.

2.4. Determination of Moisture Content

Moisture content was determined using the oven-drying method. A 2 g sample of the sawdust powder was weighed into a pre-dried and pre-weighed crucible using an analytical balance (Mettler Toledo, accuracy ±0.0001 g). The sample was placed in a hot-air oven (Memmert, UF55) set at 105°C and dried for 24 hours to constant weight. After drying, the crucible was cooled in a desiccator to prevent moisture reabsorption and reweighed. The moisture content was calculated using the following equation:

Moisture content (%) = $\frac{wi - wf}{wi} * 100$

Where W_i = initial weight of the sample (g)

W_f = Final weight of the sample (g)

2.5. Determination of Ash Content

Ash content was determined by incinerating the sample to remove organic matter, leaving inorganic residues. A 2 g sample of the sawdust powder was weighed into a pre-ignited and pre-weighed porcelain crucible. The sample was placed in a muffle furnace (Carbolite, ELF 11/6B) and heated at 550°C for 4 hours to ensure complete combustion of organic material. After incineration, the crucible was cooled in a desiccator and weighed. The ash content was calculated as follows:

Ash Content (%) = $\frac{wa}{ws} * 100$

Where W_a = initial weight of the sample (g)

W_s = Final weight of the sample (g)

2.6. Determination of Volatile Matter

The volatile matter content was determined by heating the sample under controlled conditions to release volatile components. 2 g sample of the sawdust powder was weighed into a pre-weighed covered crucible to limit oxygen exposure. The crucible was placed in a muffle furnace set at 900°C for 7 minutes, following ASTM D1762-84 standards. After heating, the crucible was cooled in a desiccator and reweighed. The volatile matter content was calculated using the equation:

Volatile Matter(%) = $\frac{wi - wv}{wi} * 100$

Where W_i = Initial Weight of the sample (g)

W_v = Final weight of the sample after heating (g)

2.7. Determination of Fixed Carbon

Fixed carbon content was calculated by difference, as it represents the non-volatile, non-ash, and non-moisture fraction of the sample. The fixed carbon content was determined using the following equation:

Fixed Carbon (%) = 100 – (Moisture content (%) + Ash content (%) + Volatile matter (%)).

2.8. Equipment and Calibration

All equipment used in the analysis, including the analytical balance, pH meter, oven, and muffle furnace, was calibrated prior to use to ensure accuracy. The analytical balance was calibrated with standard weights, and the pH meter was calibrated with buffer solutions. The muffle furnace and oven were checked for temperature accuracy using a calibrated thermocouple. All glassware and crucibles were cleaned, dried, and pre-weighed to eliminate contamination.

2.9. Data Analysis

The results of the proximate analysis were recorded as mean values from triplicate measurements, with standard deviations calculated to assess variability. The data were compared with proximate analysis results of other adsorbents (rice husk, Daniella ogen, Mangifera indica, and Azadirachta indica) reported in the literature to contextualize the properties of African-balsam sawdust. Statistical analysis was performed using Microsoft Excel to compute means and standard deviations.To ensure the reliability of the experimental results, quality control measures were strictly maintained throughout the analysis. All experiments were conducted under controlled laboratory conditions, and care was taken to minimize external contamination and measurement errors. Reagents used were of analytical grade, and deionized water was employed in all preparations to avoid interference from dissolved ions.

Additionally, repeatability and reproducibility were assessed by conducting all measurements in triplicate, and the standard deviation values were calculated to evaluate data consistency. The relatively low standard deviation values obtained indicate high precision in the experimental procedures. Instrumental calibration was performed regularly to maintain accuracy, and all measurements were recorded systematically.

Furthermore, precautionary measures such as proper handling of samples, use of desiccators to prevent moisture uptake, and adherence to standard operating procedures contributed to the overall validity of the results. These steps are critical in ensuring that the obtained data accurately reflect the intrinsic properties of the African-balsam sawdust rather than experimental variability.

3. Results and discussion

3.1. Proximate Analysis of African-Balsam Sawdust

The proximate analysis of African-balsam (*Daniela Oliveri*) sawdust powder was conducted to determine its physicochemical properties, including pH, moisture content, ash content, volatile matter, and fixed carbon. The results, based on triplicate measurements, are summarized in Table1.0, with mean values and standard deviations calculated to assess the reproducibility of the measurements.

Table 1.0: Proximate Analysis Results of African-Balsam Sawdust Powder

Sample	Ph	Moisture Cont. (%)	Ash Cont. (%)	Volatile Matter (%)	Fixed Carbon (%)
TRIAL 1	5.76	10.33	3.10	1.70	84.90
TRIAL 2	6.15	10.83	2.60	1.75	85.01
TRIAL 3	5.45	9.63	3.40	1.74	85.00
MEAN	5.79	10.26	3.03	1.73	84.97
STANDARD DEVIATION	0.40	0.60	0.40	0.03	0.06

The low standard deviations (ranging from 0.03 to 0.06) across all parameters indicate high reproducibility and reliability of the experimental measurements, confirming the consistency of the sample preparation and analytical methods employed.

3.2. pH

The pH of African-balsam sawdust powder was determined to be 5.79 ± 0.40, indicating a slightly acidic nature. This pH value is significant for adsorption applications, as it influences the surface charge of the material and its interaction with ionic pollutants. A slightly acidic pH is favorable for adsorbing cationic species, such as heavy metals (e.g., Pb^{2+}, Zn^{2+}), due to the presence of negatively charged functional groups on the lignocellulosic surface (Wang et al., 2024). The acidic nature of African-balsam sawdust provides a unique advantage for specific adsorption processes.

3.3. Moisture Content

The moisture content of the sawdust was 10.26 ± 0.60%, which is moderate compared to other biomass adsorbents. For instance, rice straw exhibits a lower moisture content of 6.85% (Jin & Chen, 2007), while Mangifera indica sawdust has a higher value of 15.61% (Elehinafe et al., 2019b). The moderate moisture content of African-balsam sawdust suggests it requires minimal drying for storage and handling, making it cost-effective for large-scale applications. High moisture content can hinder adsorption efficiency by occupying active sites, so the relatively low value observed here is advantageous for practical use (Kumar & Singh, 2023).

3.4. Ash Content

The ash content was found to be 3.03 ± 0.40%, which is higher than that of Daniella ogen (0.82%) and Mangifera indica (0.70%) but lower than rice straw (1.33%) (Table 2.0). Ash content represents the inorganic residue after combustion and can affect the material's adsorption capacity by reducing the availability of organic binding sites. The moderate ash content of African-balsam sawdust indicates a balance between organic and inorganic components, suggesting it retains sufficient lignocellulosic material for effective adsorption while maintaining structural stability (Oladipo et al., 2023).

3.5. Volatile Matter

The volatile matter content was notably low at 1.73 ± 0.03%, significantly lower than that of rice straw (18.75%), Daniella ogen (10.90%), Mangifera indica (12.52%), and Azadirachta indica (10.20%) (Table2.0). This low volatile matter content indicates a high degree of thermal stability, as volatile components are typically released during heating, leading to structural degradation. The minimal volatile matter in African-balsam sawdust suggests it can withstand high-temperature processing

Table 2.0: Comparative proximate analysis of various adsorbent

Adsorbent	pH	MC%	Ash%	Vm%	Fc%	Reference
African-balsam sawdust (*Daniela Oliveri*)	5.79	10.26	3.03	1.73	84.97	This study
Rice straw	-	6.85	1.33	18.75	71.91	Jin and Chen, 2007
Daniella Ogen	-	9.93	0.82	10.90	88.28	Elehinafe et al, 2019a
Mangifera indica	-	15.61	0.70	12.52	86.78	Elehinafe et al, 2019b
Azadirachta indica	-	10.61	0.93	10.20	87.73	Elehinafe et al, 2019c

or activation processes (e.g., carbonization) without significant mass loss, making it an excellent candidate for producing activated carbon or other high-temperature adsorption applications (Adebayo et al., 2021).

3.6. *Fixed Carbon*

The fixed carbon content was determined to be 84.97 ± 0.06%, which is higher than rice straw (71.91%) but slightly lower than Daniella ogen (88.28%), Mangifera indica (86.78%), and Azadirachta indica (87.73%) (Table 2.0). The high fixed carbon content indicates a substantial proportion of stable, non-volatile carbon, which is a critical attribute for adsorbents. A high fixed carbon content enhances the material's capacity to form porous structures during activation, improving its adsorption efficiency for pollutants such as dyes, heavy metals, and organic compounds (Zhang et al., 2025). The combination of low volatile matter and high fixed carbon positions African-balsam sawdust as a promising precursor for activated carbon production.

3.7. *Comparative Analysis with Other Adsorbents*

Table 2.0 provides a comparative overview of the proximate analysis results for African-balsam sawdust and other biomass-derived adsorbents. The most striking feature of African-balsam sawdust is its exceptionally low volatile matter (1.73%) compared to rice straw (18.75%) and other sawdusts (10.20–12.52%). This suggests superior thermal stability, which is advantageous for applications requiring high-temperature processing. The fixed carbon content (84.97%) is comparable to or higher than that of other adsorbents, reinforcing its potential as a stable carbon-based material. The moisture content (10.33%) and ash content (2.98%) are moderate, aligning closely with Azadirachta indica (10.61% and 0.93%, respectively), indicating similar handling and storage requirements.

The slightly acidic pH (5.76) of African-balsam sawdust is a unique characteristic not reported for the other adsorbents in Table 2.0. This property may enhance its selectivity for cationic pollutants, distinguishing it from neutral or alkaline biomass materials (Ghaedi et al., 2022). Compared to rice straw, which has a higher volatile matter content and lower fixed carbon, African-balsam sawdust offers a more stable and carbon-rich matrix, potentially leading to higher adsorption capacities after activation.

The physicochemical characteristics obtained from the proximate analysis provide valuable insight into the adsorption potential of African-balsam sawdust. Adsorption efficiency is strongly influenced by the structural and compositional features of a biomass precursor, particularly moisture content, ash content, volatile matter, and fixed carbon. The relatively low moisture content observed in this study suggests that a large proportion of the material's internal pores remain available for pollutant interaction. Excessive moisture often occupies adsorption sites and may reduce adsorption capacity, particularly in applications involving dissolved contaminants. Therefore, the moisture level obtained for African-balsam sawdust is advantageous for both storage stability and adsorption performance.

Similarly, the ash content provides an indication of the inorganic mineral fraction present within the biomass. Although minerals can contribute to structural rigidity, excessive ash may block pore structures and reduce the accessibility of active adsorption sites. The moderate ash content recorded in this study indicates that African-balsam sawdust contains sufficient organic constituents necessary for carbon development while maintaining adequate structural integrity. This characteristic is particularly desirable for adsorbent production because it allows efficient pore development during thermal activation processes.

The exceptionally low volatile matter content further strengthens the suitability of the material for adsorption applications. During carbonization and activation, volatile compounds are released from biomass matrices, creating pores that contribute to the final adsorbent structure. However, excessive volatile matter may result in significant mass loss and structural instability. The low volatile matter content recorded for African-balsam sawdust suggests improved thermal stability and controlled pore development, which may ultimately enhance adsorption efficiency. Consequently, the material may produce activated carbon with superior physicochemical properties compared with many conventional lignocellulosic precursors.

3.8. Implications for Adsorption Applications

The proximate analysis results highlight the potential of African-balsam sawdust as a sustainable, low-cost adsorbent for environmental applications. The high fixed carbon content and low volatile matter suggest that the material can be effectively converted into activated carbon with a high surface area and porosity, ideal for removing contaminants such as heavy metals, dyes, and organic pollutants from wastewater (Oladipo et al., 2023). The slightly acidic pH enhances its suitability for adsorbing cationic species, which are prevalent in industrial effluents. The moderate moisture and ash contents indicate that African-balsam sawdust requires minimal preprocessing, reducing production costs compared to materials with higher moisture content, such as Mangifera indica (Elehinafe et al., 2019b).

The low volatile matter content also suggests that African-balsam sawdust could be used in high-temperature applications, such as biochar production or catalytic processes, without significant mass loss (Kumar & Singh, 2023). Compared to other biomass adsorbents, its unique combination of properties positions it as a versatile material for both environmental remediation and industrial applications. However, further studies are needed to evaluate its adsorption capacity, surface area, and pore structure after activation to fully validate its performance.

The growing global emphasis on sustainable development has intensified interest in converting agricultural and forestry wastes into valuable industrial products. Sawdust generated from timber-processing activities often constitutes a significant proportion of solid waste in many developing countries. Improper disposal practices such as open burning and uncontrolled dumping can contribute to environmental pollution, greenhouse gas emissions, and land degradation. Therefore, the utilization of African-balsam sawdust as an adsorbent material represents an environmentally responsible strategy for waste valorization.

The conversion of waste biomass into adsorbents aligns with the principles of the circular economy, which encourages resource recovery, waste minimization, and sustainable material utilization. Instead of being regarded as a waste product, African-balsam sawdust can serve as a valuable raw material for the production of activated carbon and other environmental remediation materials. Such an approach not only reduces environmental burdens associated with waste disposal but also creates economic opportunities through the development of low-cost adsorbent technologies.

Furthermore, the widespread availability of African-balsam wood in several regions of Nigeria and other African countries provides a sustainable supply of raw materials. This availability may facilitate the establishment of localized adsorbent production systems capable of supporting wastewater treatment operations at relatively low cost. The adoption of such biomass-based technologies can contribute significantly to sustainable environmental management and improved access to affordable water treatment solutions.

3.9. Potential for Activated Carbon Production and Industrial Applications

One of the most promising applications of African-balsam sawdust is its utilization as a precursor for activated carbon production. Activated carbon remains one of the most effective adsorbent materials used in wastewater treatment, air purification, food processing, pharmaceutical production, and numerous industrial separation processes. However, the high cost associated with commercial activated carbon production often limits its accessibility, particularly in developing countries.

The proximate analysis results obtained in this study indicate that African-balsam sawdust possesses characteristics favorable for activated carbon manufacture. The combination of high fixed carbon content and low volatile matter is generally associated with improved carbon yield and enhanced pore development during activation. These characteristics suggest that activated carbon derived from African-balsam sawdust may exhibit desirable adsorption properties suitable for the removal of heavy metals, dyes, pesticides, pharmaceutical residues, and other emerging contaminants.

Beyond wastewater treatment, African-balsam-derived activated carbon may find applications in gas purification systems, odor control technologies, catalyst support materials, and energy-storage devices. The increasing demand for sustainable carbon materials in environmental and industrial sectors further highlights the importance of exploring underutilized biomass resources such as African-balsam sawdust. Consequently, the findings of this study provide a scientific basis for future investigations into the large-scale production and commercialization of biomass-derived adsorbents.

4. Conclusion

The proximate analysis of African-balsam sawdust powder reveals a slightly acidic pH (5.79 ± 0.40), moderate moisture content (10.26 ± 0.60%), low ash content (3.03 ± 0.03%), exceptionally low volatile matter (1.73 ± 0.03%), and high fixed carbon content (84.97 ± 0.06%). These properties indicate that African-balsam sawdust is a thermally stable, carbon-rich material with significant potential as a sustainable adsorbent. Its low volatile matter and high fixed carbon content distinguish it from other biomass adsorbents, such as rice straw, suggesting superior suitability for activated carbon production. These findings underscore the value of African-balsam sawdust as an eco-friendly, cost-effective material for environmental remediation and pave the way for further research into its adsorption performance.In addition, the findings of this study demonstrate the potential of African-balsam sawdust as a viable alternative to conventional adsorbents, particularly in developing regions where access to low-cost materials is essential. Its favorable physicochemical properties suggest that it can be further modified or activated to enhance its adsorption capacity for a wide range of pollutants.

Future research should focus on advanced characterization techniques such as surface area analysis, pore size distribution, and functional group identification using spectroscopic methods. Moreover, studies on adsorption kinetics, equilibrium isotherms, and real wastewater applications will provide deeper insights into its practical performance. Scaling up the production and evaluating its regeneration potential will also be crucial for industrial adoption.

Overall, the utilization of African-balsam sawdust not only addresses waste management challenges but also contributes to sustainable environmental protection strategies, aligning with global efforts toward green technology and circular economy practices.

5. Limitations of the Study and Future Research Directions

Although the present study provides important baseline information regarding the proximate characteristics of African-balsam sawdust, several limitations should be acknowledged. The investigation focused primarily on proximate analysis parameters and did not include advanced physicochemical characterization techniques such as Brunauer–Emmett–Teller (BET) surface area analysis, Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD), or elemental analysis. These techniques would provide additional information regarding surface morphology, pore structure, functional groups, and chemical composition.

Furthermore, adsorption experiments involving specific contaminants were not conducted in the present study. Therefore, the actual adsorption capacity, adsorption kinetics, equilibrium behavior, and regeneration performance of African-balsam sawdust remain subjects for future investigation. Subsequent studies should evaluate the effectiveness of both raw and activated African-balsam sawdust for the removal of heavy metals, dyes, pharmaceuticals, and other priority pollutants from wastewater systems.

Future research should also examine activation methods, optimization of processing conditions, economic feasibility, and pilot-scale implementation. Such investigations will provide a more comprehensive understanding of the practical applicability of African-balsam sawdust as a sustainable adsorbent material and support its integration into environmental remediation technologies.

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