MACEIÓ - ALAGOAS
EBA 15
15° ENCONTRO BRASILEIRO SOBRE ADSORÇÃO
15th Brazilian Meeting about Adsorption

Synthesis, Characterization, and Application of Biomass for the Adsorption of Emerging Contaminants.

Vitor Barbosa Marques[a], Kauê Sodré Pereira[b], Danilo Rodrigues de Souza[a,b,*]

[a] *Vitor UFOB, R. da prainha, nº. 1326 - Morada Nobre, Barreiras, 47810-047, Brasil*
[b] *Kauê UFOB, R. da prainha, nº. 1326 - Morada Nobre, Barreiras, 47810-047, Brasil*
[a,b*] *Danilo UFOB, R. da prainha, nº. 1326 - Morada Nobre, Barreiras, 47810-047, Brasil*

Abstract

The production of activated carbon from banana peel has emerged as a sustainable and promising alternative for the utilization of agricultural waste. Banana peel, which is abundant and low-cost, has ideal characteristics for the production of activated carbon, such as high porosity and carbon content. This material is widely used in water purification processes and contaminant removal. Recent studies show that activated carbon produced from banana peel has excellent adsorption capacity for contaminants such as dyes, heavy metals, and organic compounds. Optimizing production parameters, such as activation temperature and carbonization time, can further enhance its efficiency. Thus, using banana peel for the production of activated carbon not only offers a solution for waste management but also contributes to the creation of high-value materials with important environmental applications. In this work, the contaminant used is caffeine.

Keywords: Adsorption; Kinetics; Isotherms; Activated Carbon; Caffeine.

1. INTRODUCTION

The production of activated carbon from agricultural waste, such as banana peel, has gained prominence in recent years due to the growing demand for efficient and environmentally friendly adsorbent materials.

The efficiency of activated carbon in adsorbing different substances is generally evaluated through kinetic and adsorption isotherm studies. Adsorption kinetics provide information on the rate and mechanism by which contaminants are adsorbed onto the surface of activated carbon. Common kinetic models include the pseudo-first-order and pseudo-second-order models, which help to understand the behavior of the adsorption process over time [1].

Adsorption isotherms, in turn, describe the relation between the amount of adsorbate adsorbed per unit mass of adsorbent and the concentration of the adsorbate in solution at equilibrium. Isotherm models, such as Langmuir and Freundlich, are largely used to characterize the adsorption capacity and affinity of activated carbon for different substances [2].

2. METHODOLOGY

Figure 1: Biomass Preparation

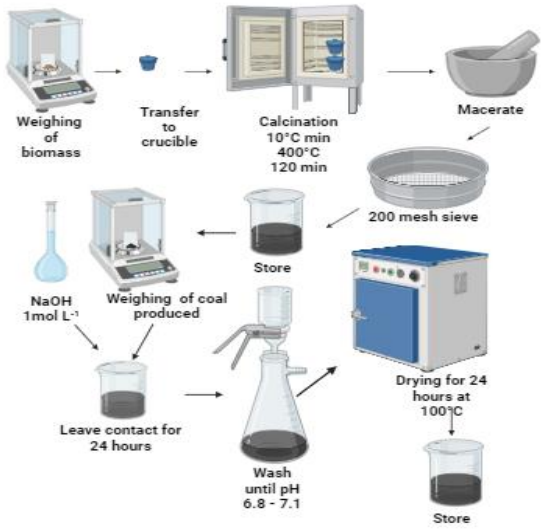

Figure 2: Calcination and Activation

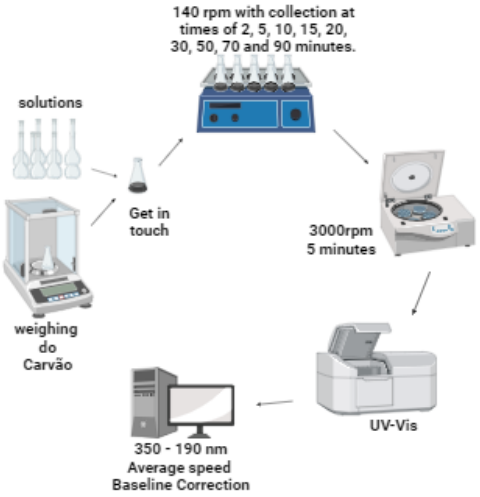

Figure 3: Adsorption Kinetics

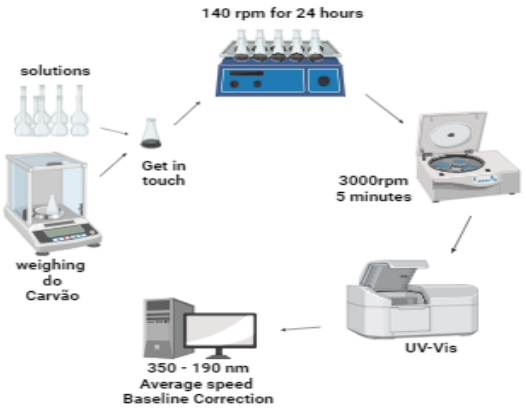

Figure 4: Adsorption Isotherms

3. Results

3.1 Adsorption Kinetics

The pseudo-first-order kinetic model is based on the adsorption capacity of the adsorbent and is a widely used mathematical model to describe the adsorption of liquids onto solids [3].

The pseudo-second-order model, suggested by [4], posits that the reaction rate depends on the amount of solute adsorbed on the surface of the adsorbent and the amount adsorbed at equilibrium.

The non-linearized pseudo-first-order (PPO) and pseudo-second-order (PSO) models were adjusted to the experimental adsorption kinetics data of commercial activated carbon (CAC), produced carbon (PC), and produced activated carbon (PAC).

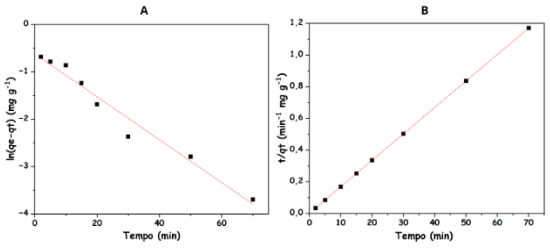

Figure 5: (A) PPO CAC Kinetics (B) PSO CAC Kinetics.

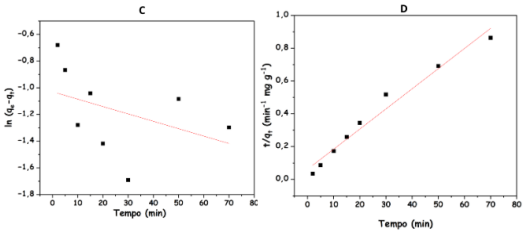

Figure 6: (C) PPO CP Kinetics (D) PSO CP Kinetics.

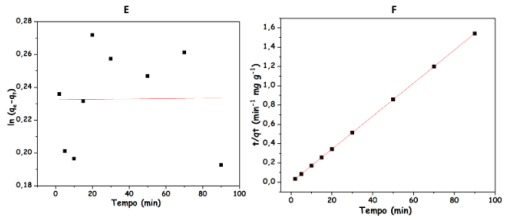

Figure 7: (E) PPO CPA Kinetics (F) PSO CPA Kinetics.

Among the kinetic models studied, the pseudo-second-order model provided the best fit for the experimental data, as this model showed higher R^2 values and lower Δqe values, as shown in Table 1.

Table 1: adsorption kinetics data

CAC	qe	R^2
1º Order	0,5392	0,9658
2º Order	1,0008	1
CP	qe	R^2
1º Order	0,3572	0,0311
2º Order	1,0632	0,9677
CPA	qe	R^2
1º Order	1,2618	-0,1427
2º Order	1,0001	1

Additionally, it can be observed that the values of the maximum adsorption capacity from the model (qe) were similar to the experimental value (qe,exp). Since the initial concentration of caffeine is low, the adsorption kinetics are likely slower, which favors the pseudo-second-order model.

3.2 Adsorption Isotherms

The purpose of adsorption isotherms is primarily to determine the mechanism of interaction between caffeine molecules and commercial activated carbon. [5] provide an identification of adsorption isotherm curves and suggest that their form can be used to indicate the adsorption mechanism, the physical nature of the solute, the substrate surface, and the specific surface area of the product [6].

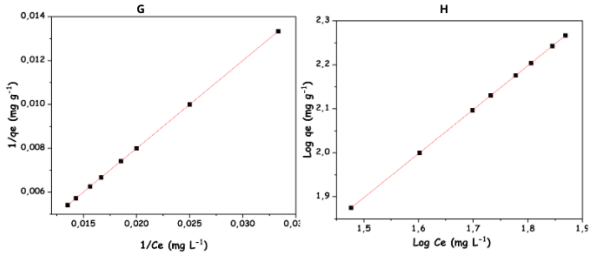

Figure 8: (G) Langmuir Isotherm CAC (H) Freundlich Isotherm CAC.

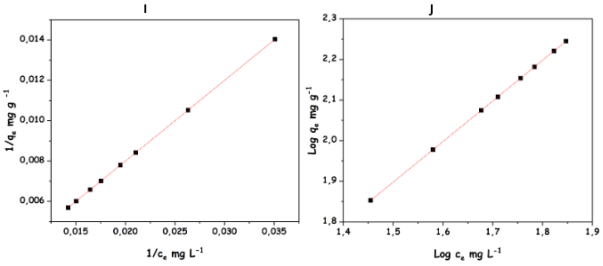

Figure 9: (I) Langmuir Isotherm CP (J) Freundlich Isotherm CP.

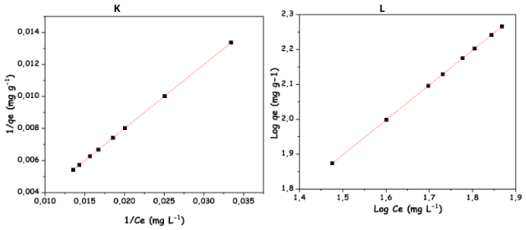

Figure 10: (K) Langmuir Isotherm CPA (L) Freundlich Isotherm CPA.

In the adsorption of caffeine, both the commercial activated carbon, the produced carbon, and the activated produced carbon best fit the Freundlich model. This can be better evaluated by analyzing the R^2 value determined for each model fit based on the linearized equations.

The obtained parameters are described in Table 2.

Table 2: adsorption isotherm data

Model	Parameter	CAC	CP	CPA
Freundlich	**R^2**	0,398	0,398	2,513
	Q_{max}	2,513	2,513	1,489
	K_F	0,398	0,398	2,513
	R_F	0,048	0,048	0,008
Langmuir	**R^2**	0,995	1	1
	Q_{max}	-40,650	-9,61	1
	R_L	-0,0474	1	2,78
	R_2	0,9954	1	1

Such a result indicates that the adsorption did not occur in a monolayer; rather, it occurs in multiple layers and on a heterogeneous surface, which shows a relationship between the amount of solute incorporated into the adsorbent material and its concentration until the system reaches equilibrium.

4. Conclusion

The results obtained showed that the Freundlich model provided the best fit to describe the adsorption equilibrium, indicating either a monolayer/heterogeneous adsorption, respectively. Additionally, the kinetic analysis revealed that the adsorption follows a pseudo-second-order behavior, suggesting that the rate-limiting step of the process may be chemisorption.

5. References

[1] Ho, Y. S., & McKay, G. (1999). Pseudo-second order model for sorption processes. *Process Biochemistry*, 34(5), 451-465.
[2] Foo, K. Y., & Hameed, B. H. (2010). Insights into the modeling of adsorption isotherm systems. Chemical Engineering Journal*, 156(1), 2-10.
[3] Filho, A. N. (2017). *Modelos de Adsorção: Teoria e Aplicações*. São Paulo: Editora Científica.
[4]LAGERGREN, S. (1898). Zur Theorie der Sogenannten Adsorption Gelöster Stoffe. Bihang till Kungliga Svenska Vetenskapsakademiens, Handlingar, 24/II (4): 1-39.
[5] HO Y.S., MCKAY G., DAJ, W. & FOSTER, C.F. (2000). Study of the sorption of divalent metal ions on to peat. Adsorption Science & Technology, 18(7): 639-650.
[6] GILES, C. H., MACEWAN, T. H., NAKHWA, S. N., & SMITH, D. A system of classification of solution adsorption isotherms, and its use in diagnosis of adsorption mechanisms and in measurement of specific surface areas of solids. J. Chem. Soc, 111, 3973-3993,1960.