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Synergistic Effect of the Parameters Affecting Morphological and Magnetic Properties of Magnetic Activated Carbons from Chestnut Industrial Wastes

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Introduction

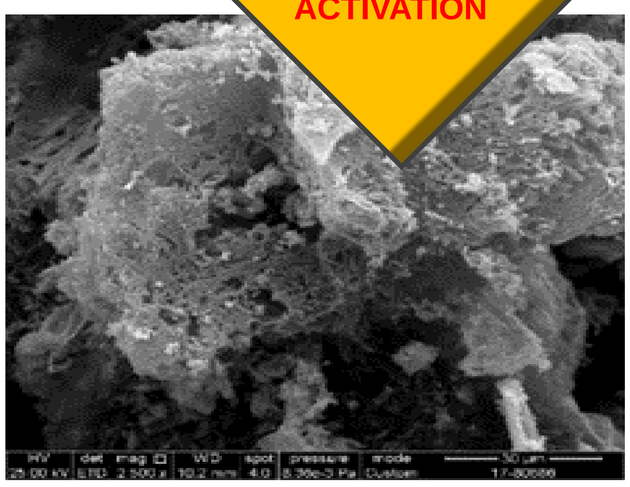
❖Activated carbons are adsorbent materials that have a good textural development and are widely used in different environmental applications. Chestnut shell waste is studied.

❖A design of experiments (DoE) was carried out using the "Design Expert 7.0" software based in the analysis of variance (ANOVA)

❖The factors under consideration were $FeCl_3$ addition from 20% to 50% (from 0.25:1 to 1:1 of $FeCl_3$:CH ratio), and activation temperature from 220ºC to 800ºC.

❖The responses studied were Density (g/cm^3), BET surface area (m^2/g), V_{TOT} and W_0 (cm^3/g), remanence (MR) and saturation magnetization (MS) (emu/g), percent of chemical element (H) and ash content.

$FeCl_3$ ACTIVATION



Results & Discussion

Table 2. ANOVA results for every response analyzed

Responses	Model/Factors	F-value	p-value	R Squared of the model
Density (g/cm^3)	Model (Quadratic)	170.63	<0.0001	0.9861
BET Surface (m^2/g)	Model (Quadratic)	15.38	<0.0001	0.8650
V_{TOT} (cm^3/g)	Model (Linear)	35.88	<0.0001	0.8271
W_0 (cm^3/g)	Model (Quadratic)	23.90	<0.0001	0.9088
Ms (emu/g)	Model (Linear)	52.09	<0.0001	0.8815
MR (emu/g)	Model (Linear)	207.95	<0.0001	0.9674
Ash (%)	Model (2FI)	96.90	< 0.0001	0.9541
H (%)	Model (Linear)	93.82	< 0.0001	0.9260

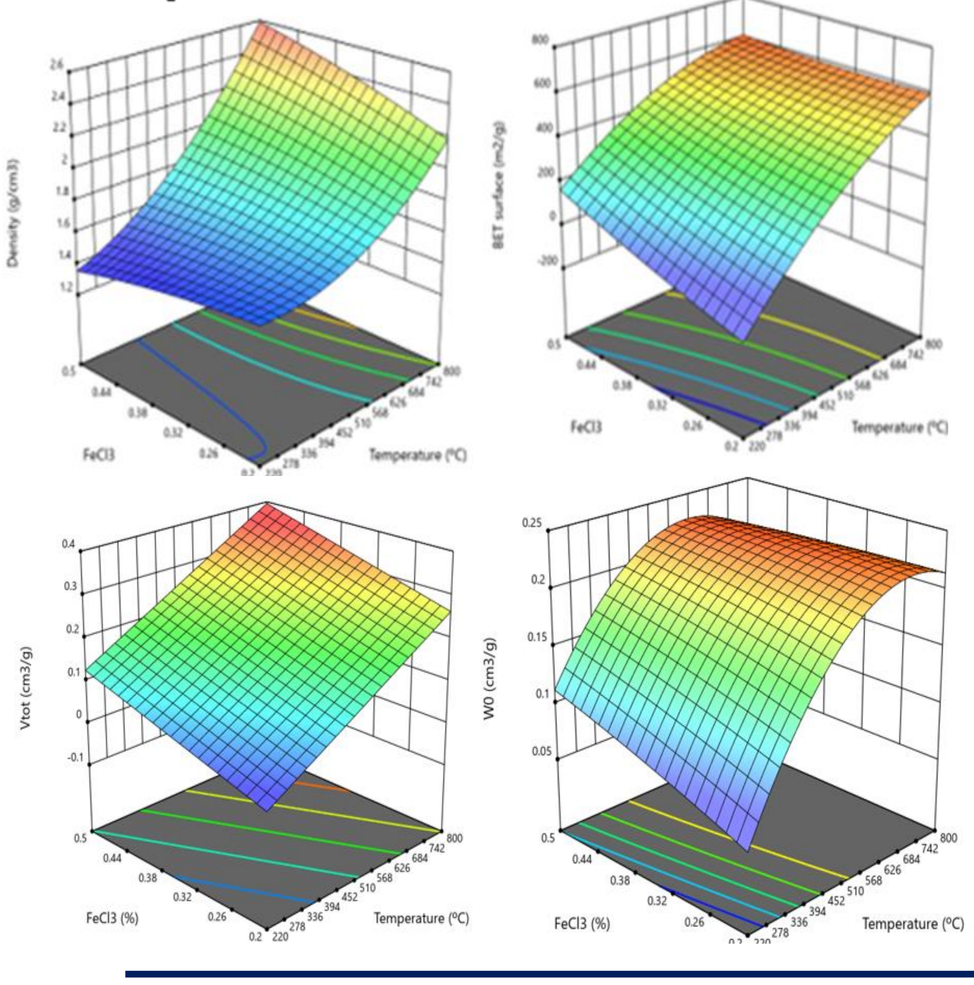
Table 1. Samples and results studied [1,2]

T (ºC)	$FeCl_3$ (%)	Density (g/cm^3)	BET surface (m^2/g)	V_{TOT} (cm^3/g)	W_0 (cm^3/g)	MS (emu/g)	MR (emu/g)	Ash (%)	H (%)
220	33	1.48	3	0.017	0.078	2.9	0.15	2	3.59
400	20	1.56	57	0.028	0.148	3.4	0.2	12.94	2.46
400	33	1.69	285	0.145	0.183	2.9	0.2	12.94	2.69
400	50	1.59	289	0.208	0.188	3.3	0.2	10.59	2.68
500	20	1.68	424	0.179	0.203	7.8	0.4	19.00	2.15
500	33	1.71	451	0.209	0.213	11.8	0.5	16.00	2.05
500	50	1.73	512	0.317	0.229	13.5	0.8	22.00	2.14
600	20	1.88	389	0.161	0.201	10.1	0.7	21.00	1.41
600	33	1.9	380	0.179	0.219	8.6	0.5	25.00	1.30
600	50	2.02	558	0.34	0.208	16.3	2.1	25.00	1.42
700	33	2.1	518	0.241	0.238	30.8	3.88	25.25	1.03
800	20	2.17	653	0.351	0.229	32	3.9	24.00	0.81
800	33	2.4	568	0.294	0.198	24.7	3.6	34.50	0.59
800	50	2.6	638	0.364	0.215	--	--	38	0.68

[1] Rodríguez-Sánchez, S., Ruiz, B., Martínez-Blanco, D., Sánchez-Arenillas, M., Díez, M.A., Marco, J.F., Gorria, P., Fuente, E. (2021) Towards advanced industrial waste-based magnetic activated carbons with tunable chemical, textural and magnetic properties, Applied Surface Science, 551, https://doi.org/10.1016/j.apsusc.2021.149407.

[2] Rodríguez-Sánchez, S., Ruiz, B., Martínez-Blanco, D., Sánchez-Arenillas, M., Díez, M.A., Suárez-Ruiz, I., Marco, J.F., Blanco, J., Fuente, E. (2019) ACS Sustainable Chemistry & Engineering 7 (20), 17293-17305. DOI: 10.1021/acssuschemeng.9b04141.

Response Surfaces



Mathematical Models

$$Density = 1.8979 - 0.0018\,T - 0.006806\,FeCl3 + 0.000035\,T \cdot FeCl + 2.17 \cdot 10^{-06}\,T^2$$

$$BET\ surface\left(\frac{m2}{g}\right) = -776.925 + 2.6212\,T + 893.6424\,FeCl3$$

$$Vtot\left(\frac{cm3}{g}\right) = -0.1957 + 0.000464\,T + 0.4412\,FeCl3$$

$$W0\left(\frac{cm3}{g}\right) = -0.2108 + 0.001126\,T + 0.3793\,FeCl3 - 0.00042\,T \cdot FeCl3 - 7.49 \cdot 10^{-07}\,T^2$$

$$\sqrt{MS}\left(\frac{emu}{g}\right) = -0.2108 + 0.001126\,T + 0.3793\,FeCl3 - 0.00042\,T \cdot FeCl3 - 7.49 \cdot 10^{-07}\,T^2$$

$$log\,10\,MR\left(\frac{emu}{g}\right) = -0.2108 + 0.001126\,T + 0.3793\,FeCl3 - 0.00042\,T \cdot FeCl3 - 7.49 \cdot 10^{-07}\,T^2$$

$$Ash\,(\%) = +12.5151 + 0.005539\,T - 57.033\,FeCl3 + 0.1267\,T \cdot FeCl3$$

$$H\,(\%) = +2.10 - 1.40\,T + 0.0028\,FeCl3$$

Conclusions

❖For all responses studied the relationship between factors and mathematical models were obtained being temperature the main factor that affects significantly on all the responses.

❖While varying the $FeCl_3$ ratio affects significantly on density, BET surface and V_{TOT}, but has little effect on W_0. For the magnetic parameters studied, once the activated carbon is magnetized, increases in the $FeCl_3$ ratio do not have a significant effect on the final responses.

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