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Influence of Synthesis Parameters on the Structure–Property Relationship and Antibacterial Performance of EU/MMT–ZnO Nanocomposites

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Introduction

The additives industry for polymeric materials seeks innovative, non-toxic antibacterial solutions for applications in active packaging and medical devices. Antibacterial nanocomposites, particularly those containing erucamide, montmorillonite and zinc oxide nanoparticles (EU-MMT-NPZn), show promise in extending food shelf life and supporting sterilization. In this study, EU-MMT-NPZn nanocomposites were synthesized via hydrothermal methods, with synthesis parameters systematically varied to optimize antibacterial properties. Results demonstrated that lower montmorillonite concentrations enhanced antibacterial activity, especially against *Staphylococcus aureus* and *Escherichia coli*

Methodology

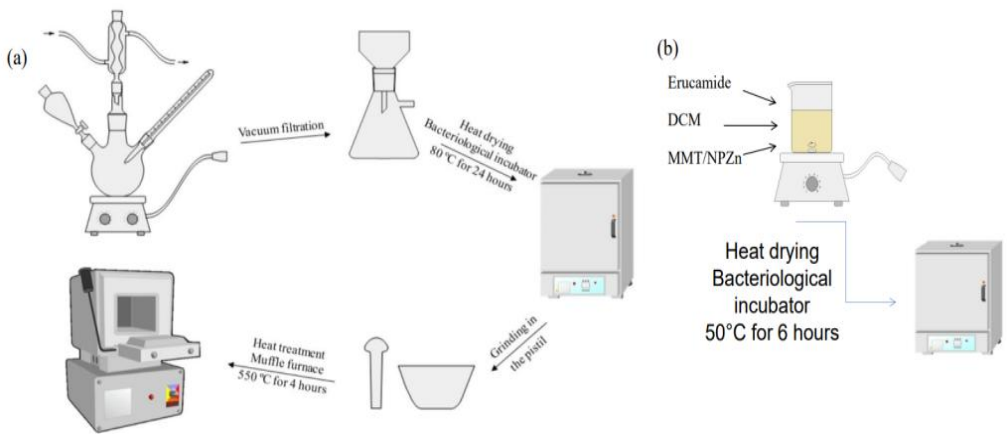


Figure 1. Methodology for obtaining the nanocomposite, from the incorporation of zinc into montmorillonite to the incorporation of erucamide into the system

Results & Discussion

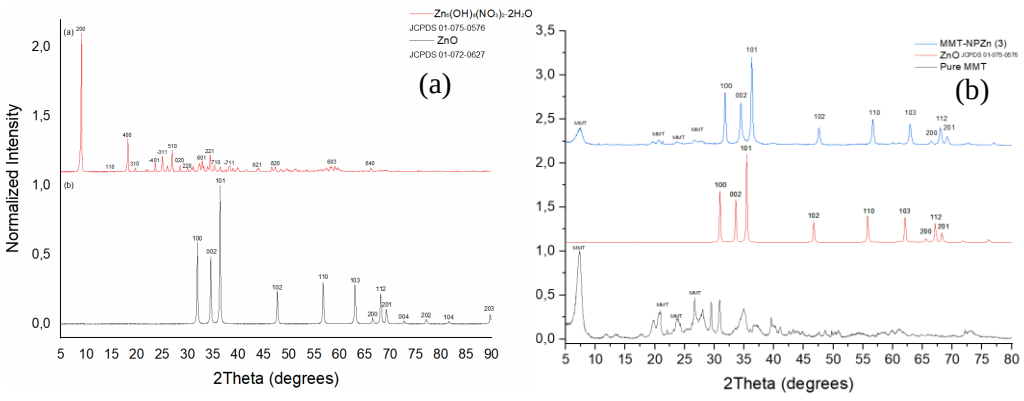


Figure 2. XRD of nanoparticles of zinc before and after thermal treatment (a) and XRD of Pure MMT, Pure ZnO (JCPDS 01-075-0576) and sample 3 of MMT-NPZn (b).

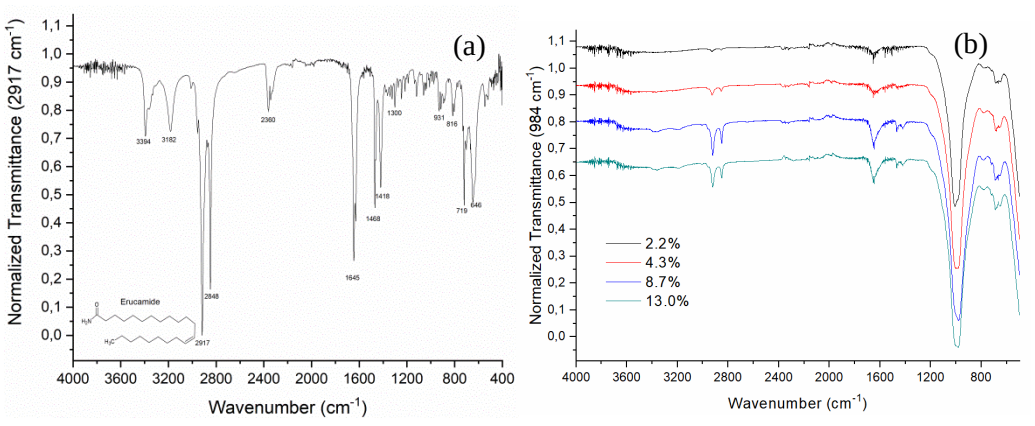


Figure 3. FTIR Spectra of (a) pure erucamide and (b) EU-MMT/ZnO nanocomposites with varying erucamide concentrations (2.2%, 4.3%, 8.7%, and 13.0%).

Exp	T (°C)	Zn Flow rate (mL/min)	t (h)	MMT (g/100mL)	IA_{SA} (cm^2)	σ_{SA} (cm^2)	IA_{EC} (cm^2)	σ_{EC} (cm^2)	d (nm)	Zn (%)	η (%)
MMT	80.0 (0)	0.00	4 (-1)	4.00 (+1)	0.00	0.00	0.00	0.00	----------	0.0	0.0
ZnO	80.0 (0)	1.00 (-1)	4 (-1)	0.00	3.04	0.18	0.00	0.00	106,98	80.34	0.0
1	85.0 (+1)	3.00 (+1)	12 (+1)	4.00 (+1)	3.47	0.33	0.00	0.00	78,81	30.94	25.66
2	75.0 (-1)	3.00 (+1)	12 (+1)	4.00 (+1)	3.69	0.19	0.00	0.00	74,76	32.28	27.51
3	85.0 (+1)	1.00 (-1)	12 (+1)	4.00 (+1)	3.25	0.19	0.00	0.00	67,00	38.43	37.46
4	75.0 (-1)	1.00 (-1)	12 (+1)	4.00 (+1)	3.25	0.19	0.00	0.00	65,93	21.41	14.98

Table 1. Effect of experimental designer with the variables temperature (T), zinc precursor (Zn Flow rate), time (t), concentration of montmorillonite in water (MMT), the particle medium size by Scherrer's equation (d), the antibacterial inhibition area (IA) of nanocomposites with standard errors (σ), percentage of zinc on the nanocomposite (Zn%) and the efficiency of the ZnO incorporation process (η).

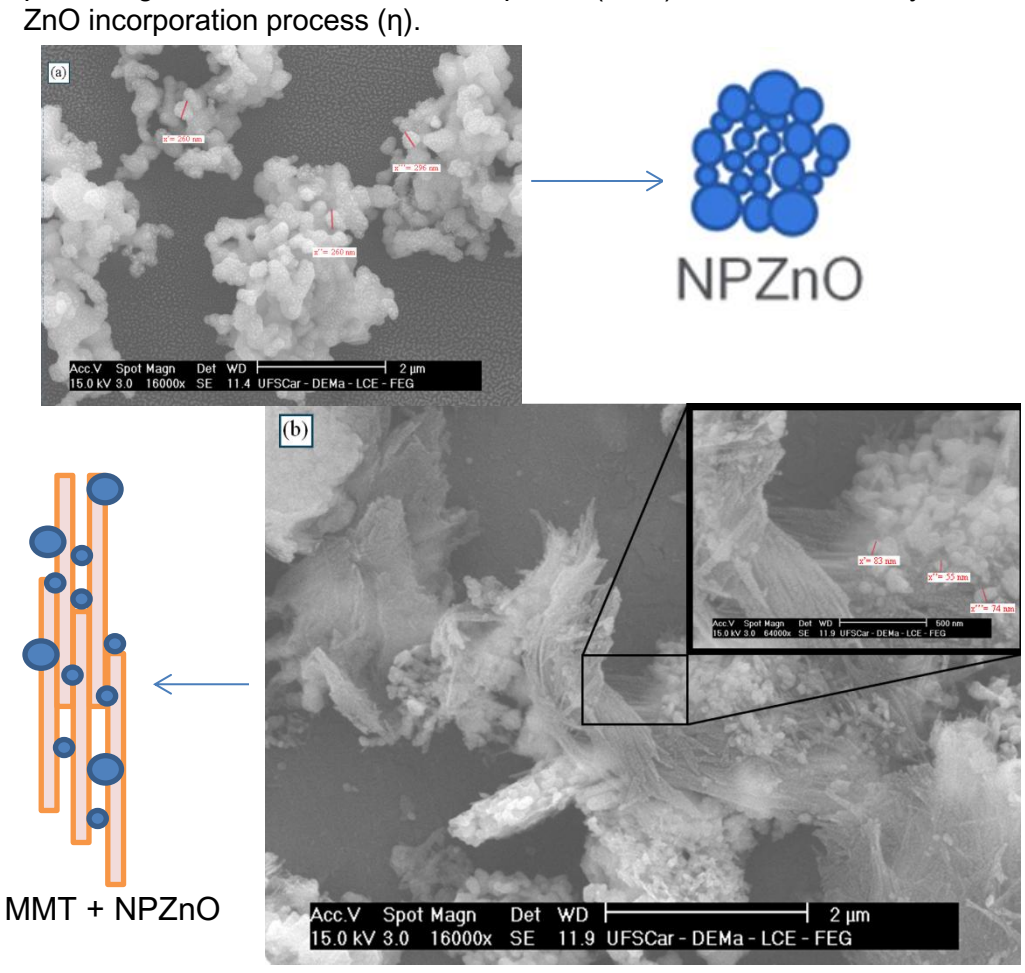


Figure 4. SEM images of (a) pure ZnO synthesized under the proposed conditions, (b) EU-MMT/NPZnO and (c) Highlight of the nanocomposite showing ZnO nucleation within the basal spacing of montmorillonite (MMT).

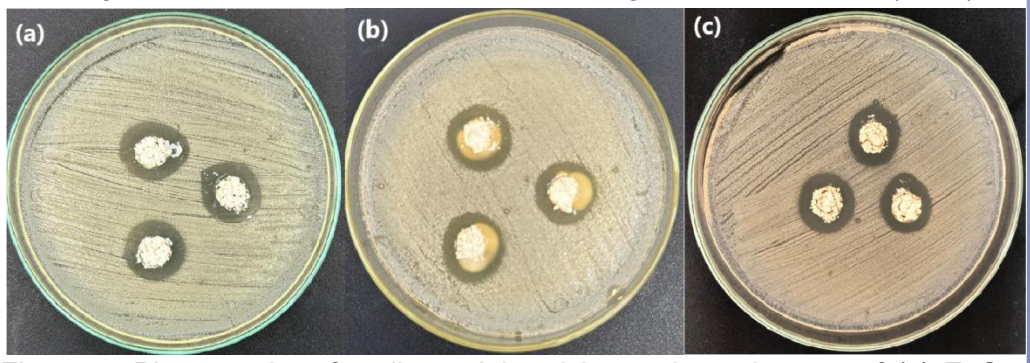


Figure 5. Photography of antibacterial activity analyses in agar of (a) ZnO against Staphylococcus aureus, (b) MMT-NPZn at best parameters (85°C; 1,00 mL/min; 12 h; 4,00 g/100mL) and (c) EU/MMT-NPZn at best parameters with 2.2% of erucamide.

Conclusions

This study confirm the effectiveness of the applied methodologies and the consistency of the executed design. The experimental design and the use of MMT proved to be important, as it resulted in an approximately decrease of 272 nm (pure ZnO) to 70.7 nm (NPZnO). The analysis results demonstrate that the nanocomposite exhibits high antibacterial activity, as it shows comparable antibacterial activity to pure ZnO despite containing, on average, only 46% ZnO in the final product.

References & Acknowledgements

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