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Development of Sustainable Antimicrobial Cellulose Additives for Melt Electrowritten PLA Fibers: From Synthesis to Extensional Rheology

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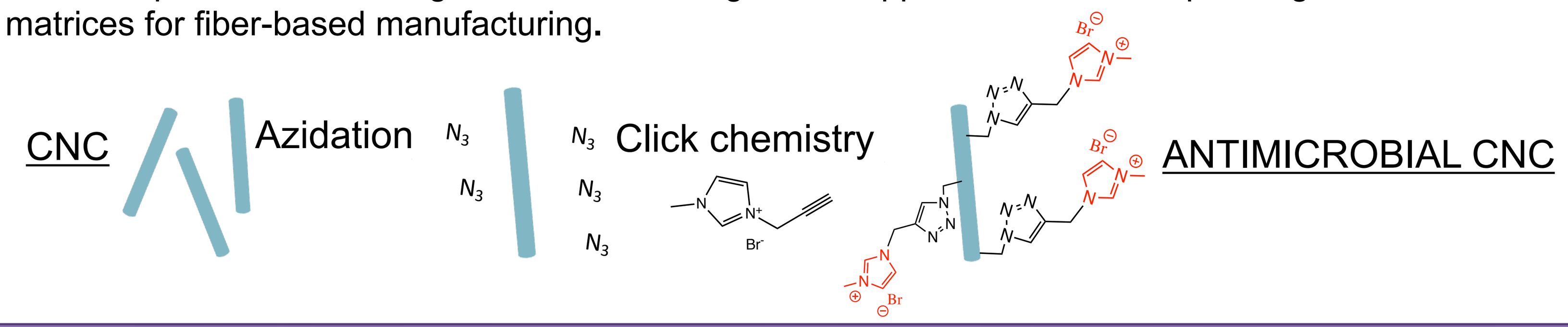
INTRODUCTION & AIM

The growing environmental concern associated with plastic waste has accelerated the search for sustainable, bio-based alternatives. Among these, cellulose nanocrystals (CNCs) stand out as renewable, biodegradable, and highly functional nanomaterials derived from natural cellulose. Their large surface area, mechanical strength, and modifiable hydroxy groups make CNCs ideal candidates for developing advanced materials with added functionalities.

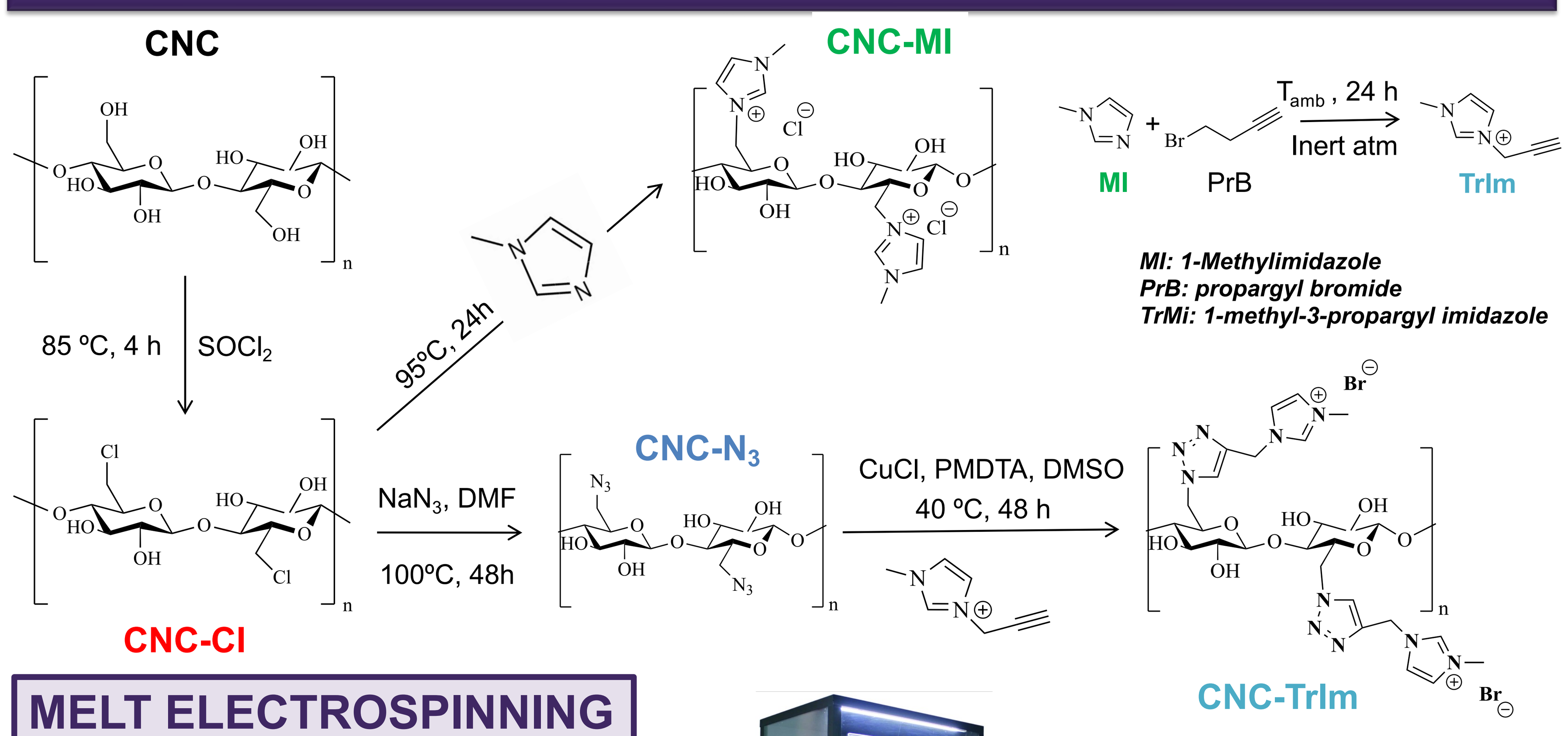
In this work, CNCs were chemically modified through the incorporation of imidazolium and triazole–imidazolium groups, aiming to impart inherent antimicrobial properties. These cationic modifications were achieved via substitution and click chemistry, and the resulting materials were extensively characterized using FTIR, NMR, XRD, and TGA analyses. The cationized CNCs exhibited strong antibacterial activity against both *Staphylococcus epidermidis* (Gram-positive) and *Pseudomonas aeruginosa* (Gram-negative), achieving reductions above 99.99%.

In addition to the antimicrobial assessment, rheological studies will be presented to evaluate how these chemical modifications influence the dispersion behavior and viscoelastic properties of CNC suspensions. This characterization provides valuable insights into the processability and potential applications of these functionalized CNCs in sustainable polymeric systems and biomedical materials.

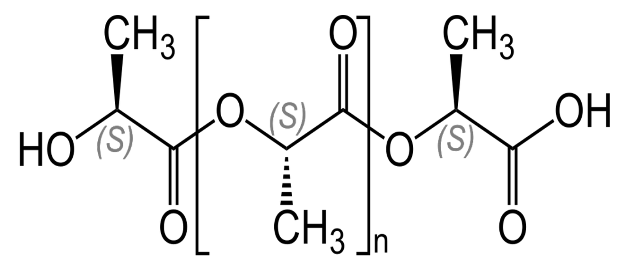
Preliminary rheological tests performed on PLA formulations containing the modified CNCs did not show the expected improvements in processability. To better understand these limitations, extensional rheology measurements were carried out in order to identify the optimal processing conditions for melt electrospinning. These results provide a first insight into the challenges and opportunities of incorporating cationic CNCs into PLA matrices for fiber-based manufacturing.



METHOD

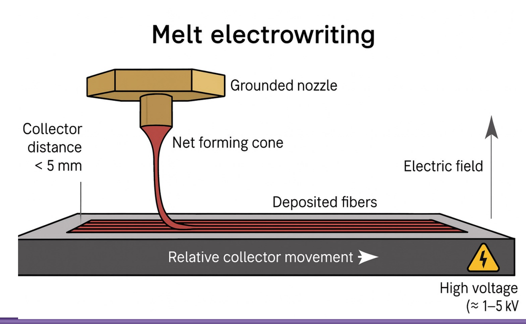


MELT ELECTROSPINNING



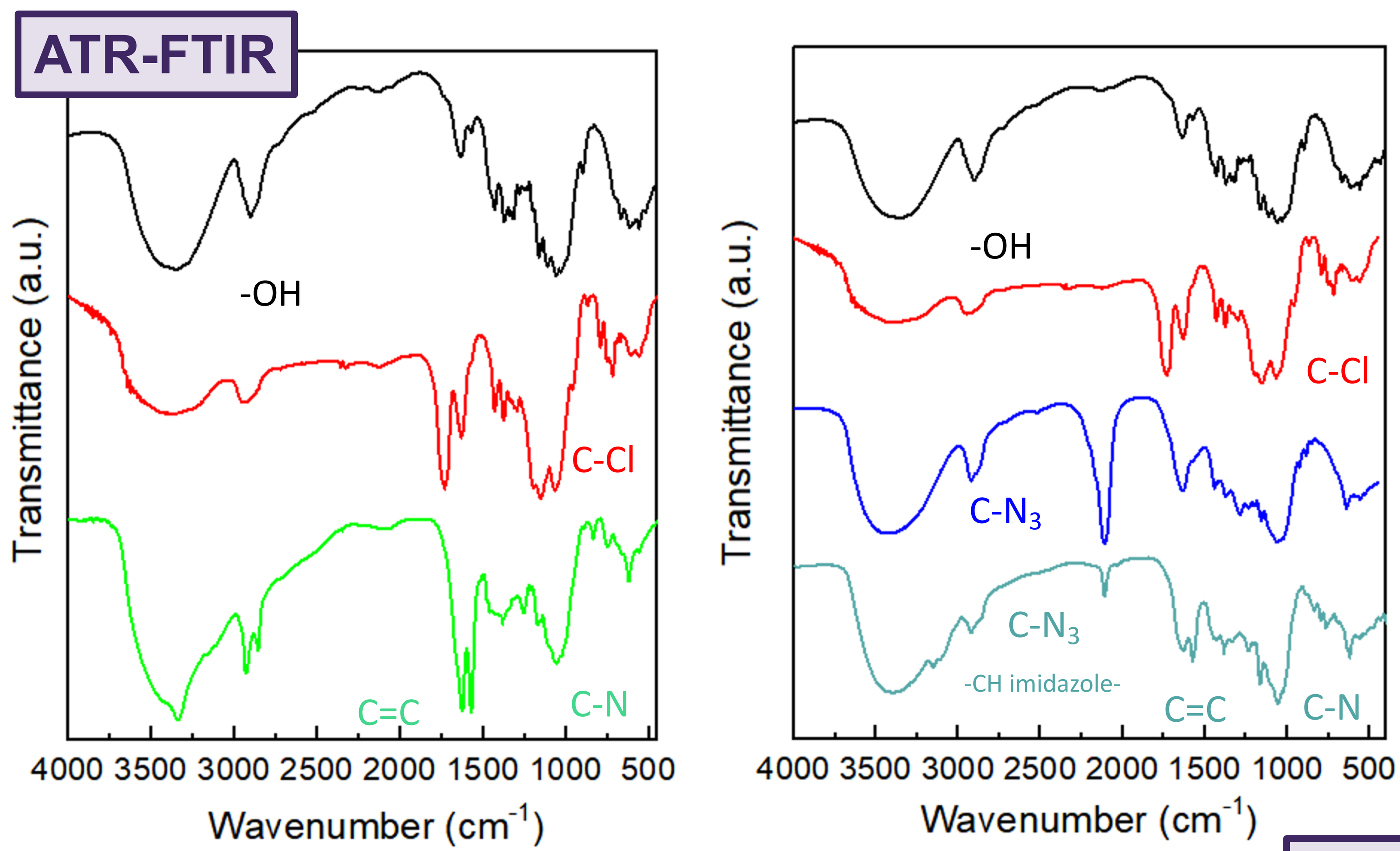
PLA 6202

NovaSpider Pro

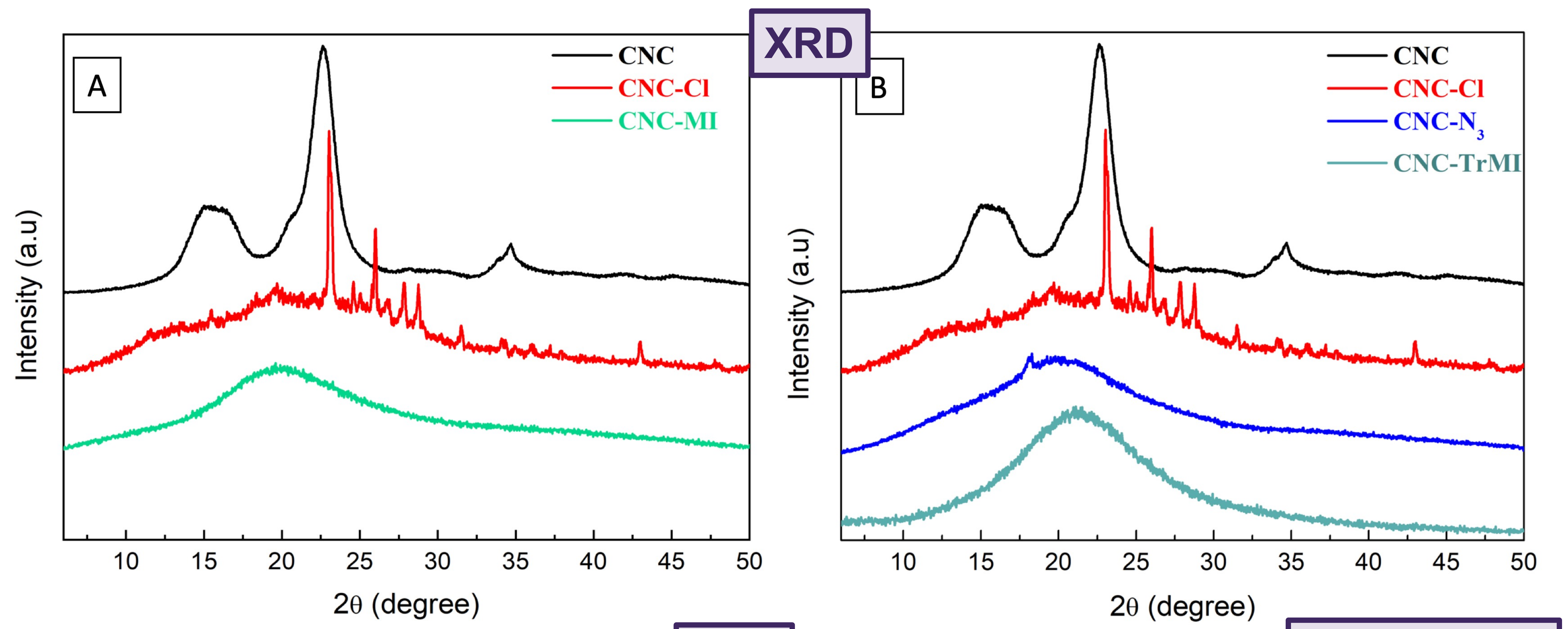


RESULTS & DISCUSSION

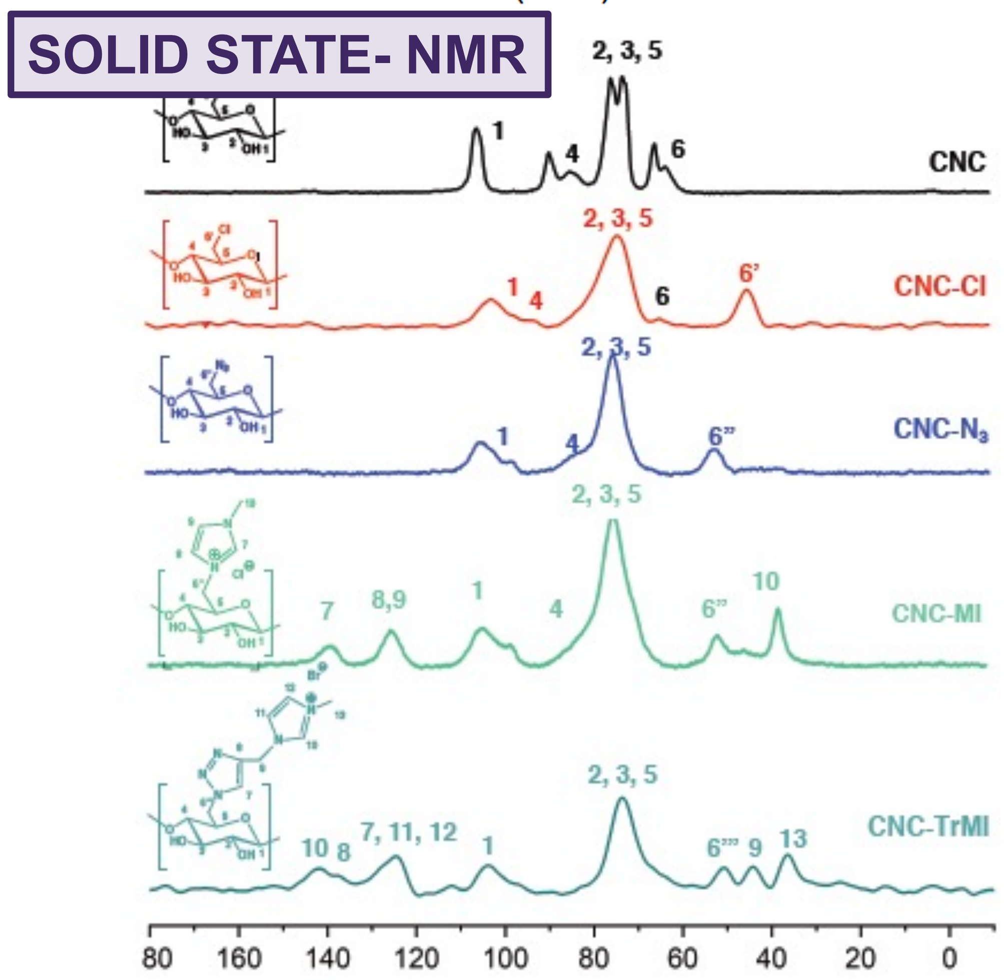
ATR-FTIR



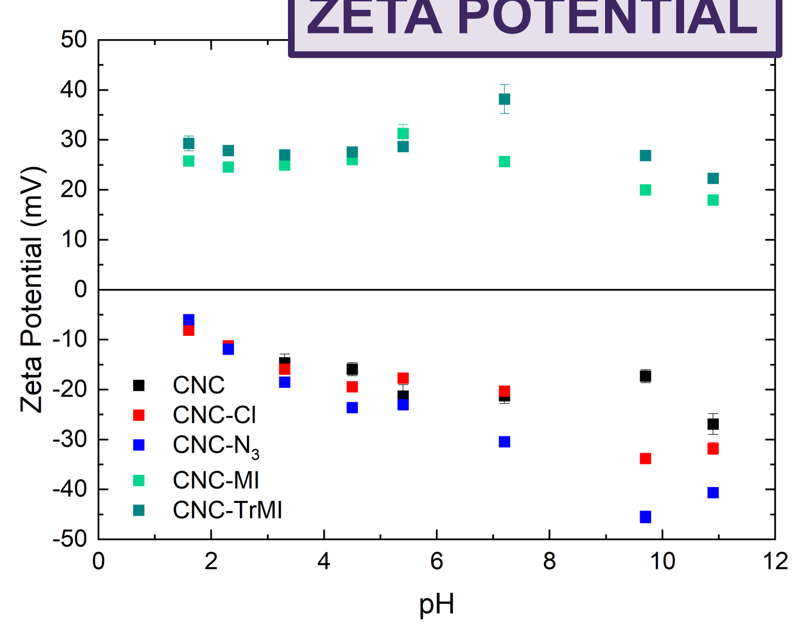
XRD



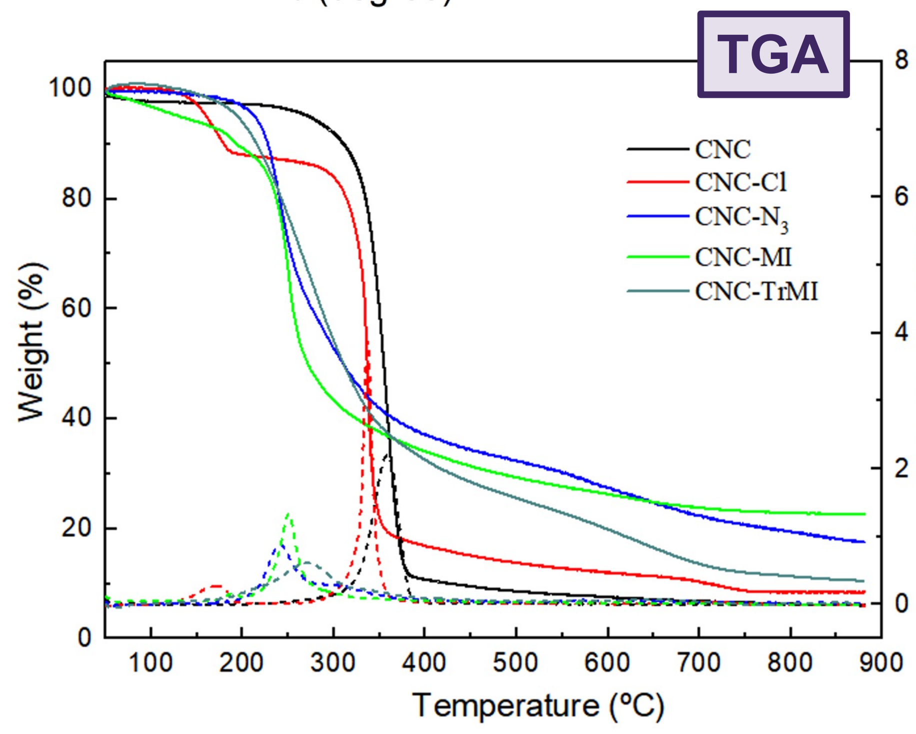
SOLID STATE- NMR



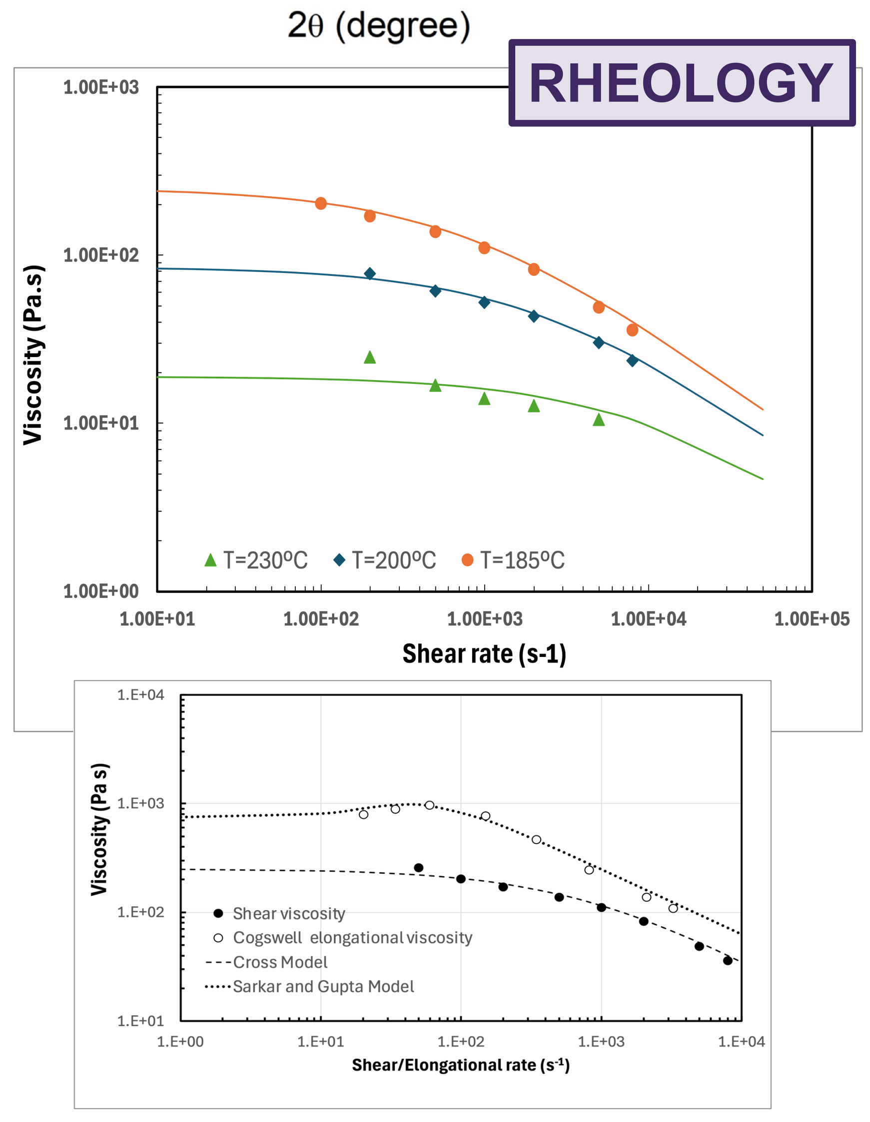
ZETA POTENTIAL



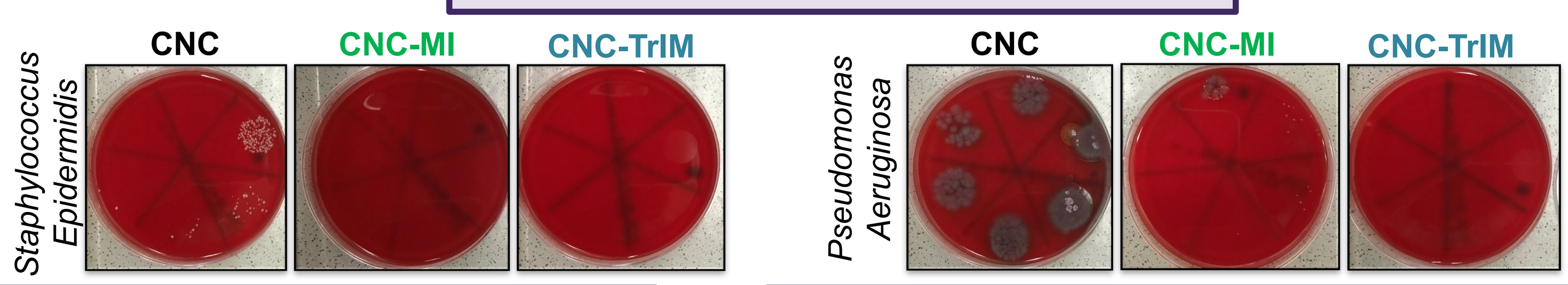
TGA



RHEOLOGY



ANTIMICROBIAL EXPERIMENTS



CONCLUSION

Microcrystalline cellulose (MCC) was successfully functionalized with imidazolium and triazole–imidazolium groups, yielding cationic materials with confirmed chemical modification and controlled degrees of substitution. These modifications reduced crystallinity and thermal stability due to structural disruption but resulted in highly effective antimicrobial activity, with the triazole–imidazolium derivative achieving >99.99% bacterial reduction for both S. epidermidis and P. aeruginosa. Overall, the results demonstrate that MCC is a sustainable and versatile platform for producing inherently antimicrobial materials, with strong potential for use in advanced polymer systems, coatings, and biomedical applications. Rheological measurements further support their processability and suitability for formulation development.

BIBLIOGRAPHY / ACKNOWLEDGMENT

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