ABSTRACT

Plastic packaging has been extensively utilized in the food sector due to its functional, inexpensive, lightweight, and extremely versatile characteristics. Thermoplastics account for the majority of plastics used in packaging applications because it can be economically formed into desired shapes, flexible in recycling, and carries out packaging functions as well. While biopolymers derived from renewable sources represent a significant advancement in food packaging towards a more sustainable society but exhibit shortcomings, particularly in terms of mechanical, and barrier properties, highlighting the need of research into advanced food packaging technologies and solutions. To address the limitations, the present research is motivated by the potential of nanotechnology and biopolymer blending, as promising strategies to enhance the functional performance of polymer-based materials for packaging applications.

Thus, the commencement of the present research work aims to improve the properties of polyvinyl alcohol (PVA) films by adding graphene oxide (GO) nanofiller to investigate the influence of different concentrations of GO (0.1 wt.% to 0.7 wt.%) on PVA/GO nanocomposite (NC) films, with the goal of determining optimal GO concentrations for improved performance. Furthermore, the study highlighted the potential of polymer blending, by analyzing the influence of carboxymethyl cellulose **(**CMC) concentrations (0.5 wt.% to 1.5 wt.%) to improve PVA properties, while promoting sustainability through the incorporation of renewable, biodegradable, and eco-friendly biopolymer. The motivation further extends to explore the potential of electrospinning technique to produce novel PVA/CMC/GO nanofiber mats with improved structural stability and functional capabilities. This explored fabrication of nanofiber mats from PVA, PVA/CMC, and PVA/CMC/GO polymer solutions by optimizing key electrospinning parameters, and to investigate the synergistic effect on the addition of GO nanofiller and CMC biopolymer in PVA to achieve uniform, and bead-free nanofiber mats.

Initially, the study demonstrated successful development of PVA/GO nanocomposite films using solution casting method with significant improvement in tensile and water vapor permeability (WVP) properties at 0.3 wt.% of GO concentrations. Significantly, the NC films also demonstrated enhanced thermal stability, UV-Vis light barrier capabilities, and antimicrobial effectiveness against *S. aureus* bacteria. Moreover, the biodegradability

tests showed PVA/GO films as an environment friendly profile, with the potential of microbial degradation against *B. subtilis* and *P. putida* bacteria. These findings demonstrate the promising potential of PVA/GO nanocomposites for industrial use, particularly in the field of packaging.

For hybrid PVA/CMC films, the addition of 0.5 wt.% concentration CMC showed improved tensile properties, and reduced WVP of 38.73% compared to neat PVA film. Thermal analysis demonstrated significant enhancement in the decomposition temperature of the hybrid PVA/CMC films, resulting in reduced thermal mass degradation compared to the PVA film. Additionally, FTIR analysis revealed that CMC incorporation led to the formation of strong hydrogen bonds within the polymeric blend, which positively influences the intermolecular forces within the cellulose matrix. Although, the films did not exhibit antibacterial activity against *S. aureus* and *E. coli,* but demonstrated efficient microbial degradation when subjected to *B. subtilis* and *P. putida* bacteria. The hybrid films also showed 40% higher degradation rate than PVA in soil burial tests, with CMC enhancing microbial breakdown and weight loss of film, highlighting their eco-friendly potential over synthetic plastics.

At last, the motivation to investigate the use of advanced electrospinning techniques for developing nanofiber mats demonstrates successful fabrication of PVA, PVA/CMC, and PVA/CMC/GO nanofiber mats. It highlights the synergistic effect of CMC biopolymer and GO nanofiller on the solution properties and the characteristics of the resulting nanofiber mats. The addition of CMC and GO notably increased the solution conductivity and viscosity, resulting in significant alteration in the nanofiber mats diameter. Rheological analysis highlighted distinct shear behaviour and enhanced storage modulus of the polymer solution with the addition of GO nanofillers. The PVA/CMC/GO nanofiber mats also exhibited an enhancement in tensile strength from 25.59% to 46.41% and significant reductions in WVP, moisture retention capacity, and water contact angle compared to neat PVA, indicating enhanced mechanical strength, hydrophilicity, and barrier properties which is favourable for packaging applications. Thermal analysis indicated that GO-induced nanofiber mats maintained the structural integrity at elevated temperatures, with minimal thermal mass degradation compared to other nanofiber formulations, while FTIR spectra confirmed the intermolecular interactions between hydroxyl groups of PVA and carboxylate groups of CMCs, with GO facilitating new H-bonds within the polymer matrix. Thus, the study confirms the synergistic impact of CMC and GO additives in improving

the structural and functional properties of nanofiber mats, making it suitable for packaging application and highlighting its potential for medical applications.

Finally, the research aspire to contribute the development, characterization and potential perspective of multifunctional hybrid packaging material with improved durability, functionality, and environmental sustainability by systematically examining the impact of GO nanofiller, and CMC biopolymer. Thus, the vision and mission of the research provides a sustainable alternative to conventional plastic for packaging materials, thereby reducing environmental harm and fostering innovation in the domain of bio-based nanocomposites.

Keywords: *Bio-composite, nanocomposite, electrospinning, packaging film, nanofiber mat, mechanical property, thermal property, antimicrobial*