Green Chemistry Approach to Enhancing Nitrile Butadiene Rubber Gloves with Biopolymers for Improved Mechanical Strength and Biodegradability

Authors : Nurhidayatullaili Muhd Julkapli, Erfan Suryani Abdul Rashid

Abstract : The use of nitrile butadiene (NBR) gloves in commercial and industrial settings has been limited due to their deficiencies in mechanical strength, biodegradability, and free radical stability. Compared to natural rubber, NBR gloves exhibit lower flexibility, strength, and puncture resistance, and they become unstable when exposed to chemical agents. Additionally, their nonbiodegradable nature presents disposal challenges. To address these issues, a multifunctional nanomaterial containing sulfonated-nanocrystalline cellulose-antioxidant (ANCC) was developed to enhance the mechanical and stability characteristics of NBR gloves while improving biodegradability. The inclusion of gallic acid (GA) antioxidants did not alter the morphology of nanocrystalline cellulose (NCC) but significantly reduced its crystallinity. Fourier Transform Infra-Red (FTIR) analysis confirmed the formation of chemical bonds between the carbonyl group and sulfonated NCC at 1645 cm-1. The efficacy of GA in both non-modified nanocellulose and sulfonated-nanocrystal cellulose-antioxidant (at a 1:4 ratio) was assessed using the DPPH test, revealing an IC50 value of less than 3mg. Various aspect ratios of NCC and ANCC were synthesized to evaluate the mechanical and thermal properties of NBR/NCC and NBR/ANCC composites at optimized loadings. NCC was produced via the acid hydrolysis method, while NBR composites were prepared using a dipping technique to simulate glove production conditions. NBR/NCC5 exhibited the highest modulus of elasticity (MOE) at 500% (8.6 MPa), with the highest elongation at break (770%) and tensile strength (27 MPa). NBR/ANCC5 demonstrated superior elongation at break (1200%) compared to pure NBR. Increased carbonyl content enhanced the surface activity of ANCC, leading to higher elongation at break due to the reaction between carbonyl and sulfonated NCC. NBR/ANCC5 composites exhibited superior biodegradability, showing an 8% weight loss difference compared to NBR/NCC5 over six months. Thermal stability increased in both NBR/NCC and NBR/ANCC composites with higher filler loading. The formation of a Zn/NCC complex and percolation network at lower NCC concentrations were crucial in enhancing the thermal stability of the nanocomposite. The interactions between Zn2+ ions and polar carbonyl and hydroxyl groups formed dative covalent bonds. Notably, commercial NBR contains some percentage of carboxylic groups, allowing the formation of dative covalent bonds with Zn2+ ions. Additionally, the highly crystalline and nanosized nature of ANCC played a key role in enhancing the flexibility and strength of NBR composites. This study introduces an alternate approach for environmentally friendly, cost-effective, and sustainable glove production by incorporating high-performance additives into NBR compounding formulas.

Keywords : biopolymer, biodegradability, environmental sustainability, green approach
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